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ENVIRONMENTAL IMPACT STATEMENT FOR DENVER TRANSPORTATION CONTROL PLAN

FIRST DRAFT

GCA CORPORATION

PREPARED FOR
ENVIRONMENTAL PROTECTION AGENCY

17 SEPTEMBER 1973

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PB 255 240

GCA
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Bedford, Massachusetts

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"Transportation control measure" has been defined by the Environmental Protection Agency (EPA), to mean any measure such as reducing vehicle use, changing traffic flow patterns, decreasing emissions from individual vehicles, or altering existing modal split patterns, that is directed toward reducing emissions of air pollutants from transportation sources. Transportation control measures are required for any air quality control region where controls on stationary sources, combined with the Federal Motor Vehicle Control Program (FMVCP) placing emission standards on new cars, are inadequate to insure attainment and/or maintenance of the ambient standards.

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Bedford, Massachusetts

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17 September 1973

ENVIRONMENTAL IMPACT STATEMENT
FOR
DENVER TRANSPORTATION CONTROL PLAN

FIRST DRAFT

The following draft submitted of the Denver Environmental Impact Statement is incomplete. Tables 13, 14, and 15 of Section IV, and Section VI will be submitted under separate cover.

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* To be completed by the U.S. Environmental Protection Agency

II. DENVER SETTING

A. PHYSICAL DESCRIPTION

1. Identification of Study Area

Colorado is the eighth largest state. It is rectangular, about 385 miles from east to west and 275 miles from north to south, and has an area of 104,247 square miles. Roughly one-third of the State, known as the "western slope," lies west of the Continential Divide. The remaining two-thirds of the State, lying east of the Divide, is referred to as the "eastern slope." Approximately 50 mountains have peaks which reach a height of 14,000 feet or more above sea level.

The State contains seven intrastate air quality control regions (AQCR's) and a part of the Four Corners Interstate AQCR. The eight AQCR's are identified by number in Figure 1. Regions 1, 2, 3, 4, and 5 lie principally to the east of the Continental Divide, and Regions 6, 7, and 8 lie principally to the west of the Divide. In this Environmental Impact Statement we are concerned with conditions within the area designated the "Study Portion of the Metropolitan Denver AQCR" in The State of Colorado Air Pollution Control Transportation and Land Use Plan. In order to avoid dividing or isolating counties within a common air drainage shed, the Denver AQCR extends eastward from the Continental Divide into the plains. It consists of the eight counties shown in Figure 2. The study portion of the AQCR, indicated by the hatched area in Figure 2, contains the principal industrial and population centers of the region. It includes, in addition to the city of Denver, the major urban centers of Boulder, Longmont and Golden, and the connecting highway systems. The Metropolitan Denver Region lies within the South Platte

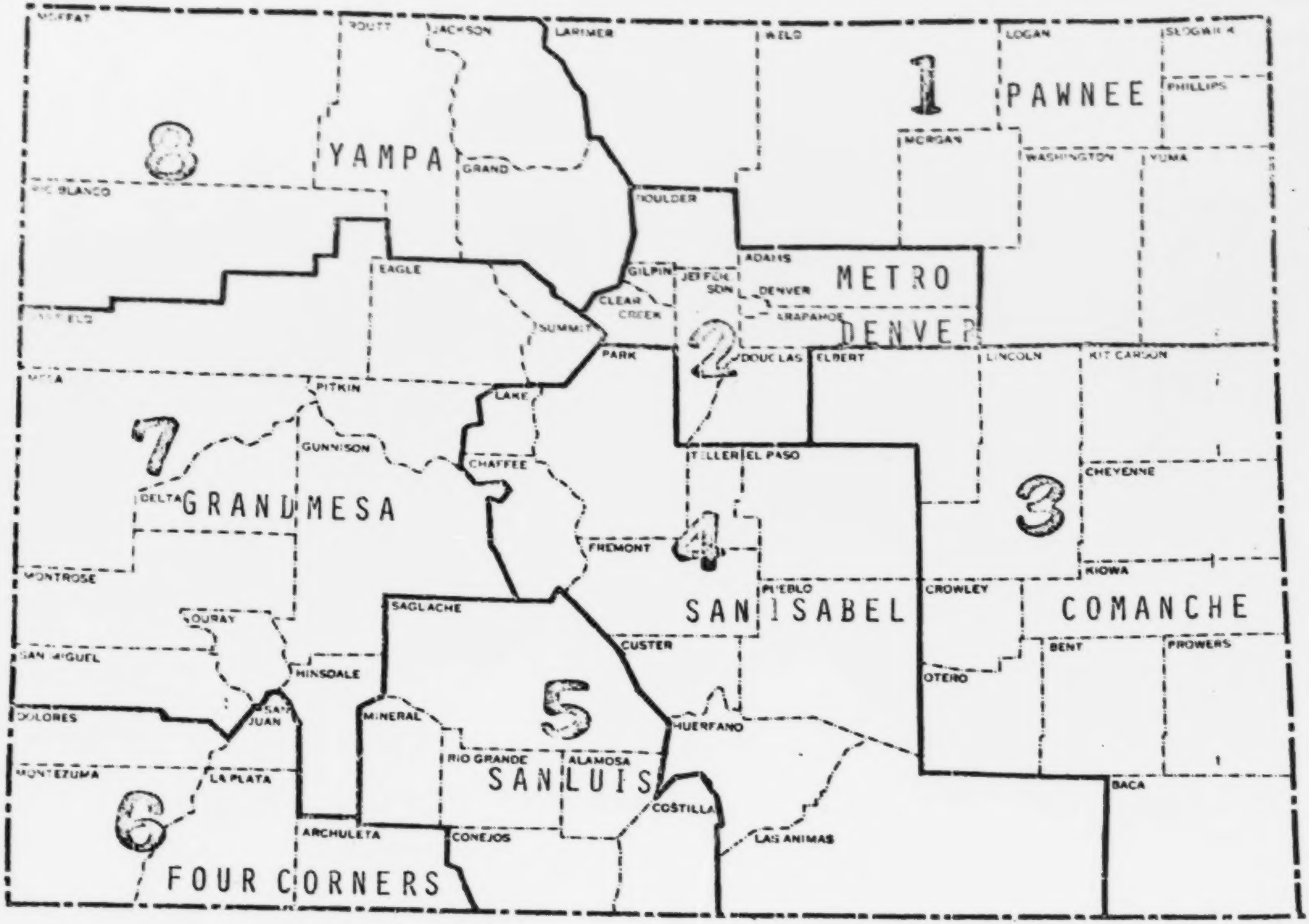

1
PAWNEE
2
METRO
DENVER
3
COMANCHE
4
SAN ISABEL
5
SAN LUIS
6
FOUR CORNERS
7
GRAND MESA
8
YAMPA
MOFFAT
ROUTT
JACKSON
LARIMER
WELD
LOGAN
SEDGWICK
PHILLIPS
MORGAN
WASHINGTON
YUMA
RIO BLANCO
GRAND
BOULDER
ADAMS
GILPIN
JEFFERSON
DENVER
ARAPAHOE
CLEAR CREEK
EAGLE
GARFIELD
SUMMIT
PARK
DOUGLAS
ELBERT
LINCOLN
KIT CARSON
MESA
PITKIN
LAKE
GUNNISON
CHAFFEE
TELLER
EL PASO
CHEYENNE
DELTA
FREMONT
KIOWA
MONTROSE
PUEBLO
CROWLEY
OURAY
SAGUACHE
SAN MIGUEL
HINSDALE
CUSTER
BENT
PROWERS
OTERO
DOLORES
SAN JUAN
MINERAL
HUERFANO
RIO GRANDE
ALAMOSA
MONTEZUMA
LA PLATA
COSTILLA
BACA
ARCHULETA
CONEJOS
LAS ANIMAS

Figure 1. Colorado Air Quality Control Regions

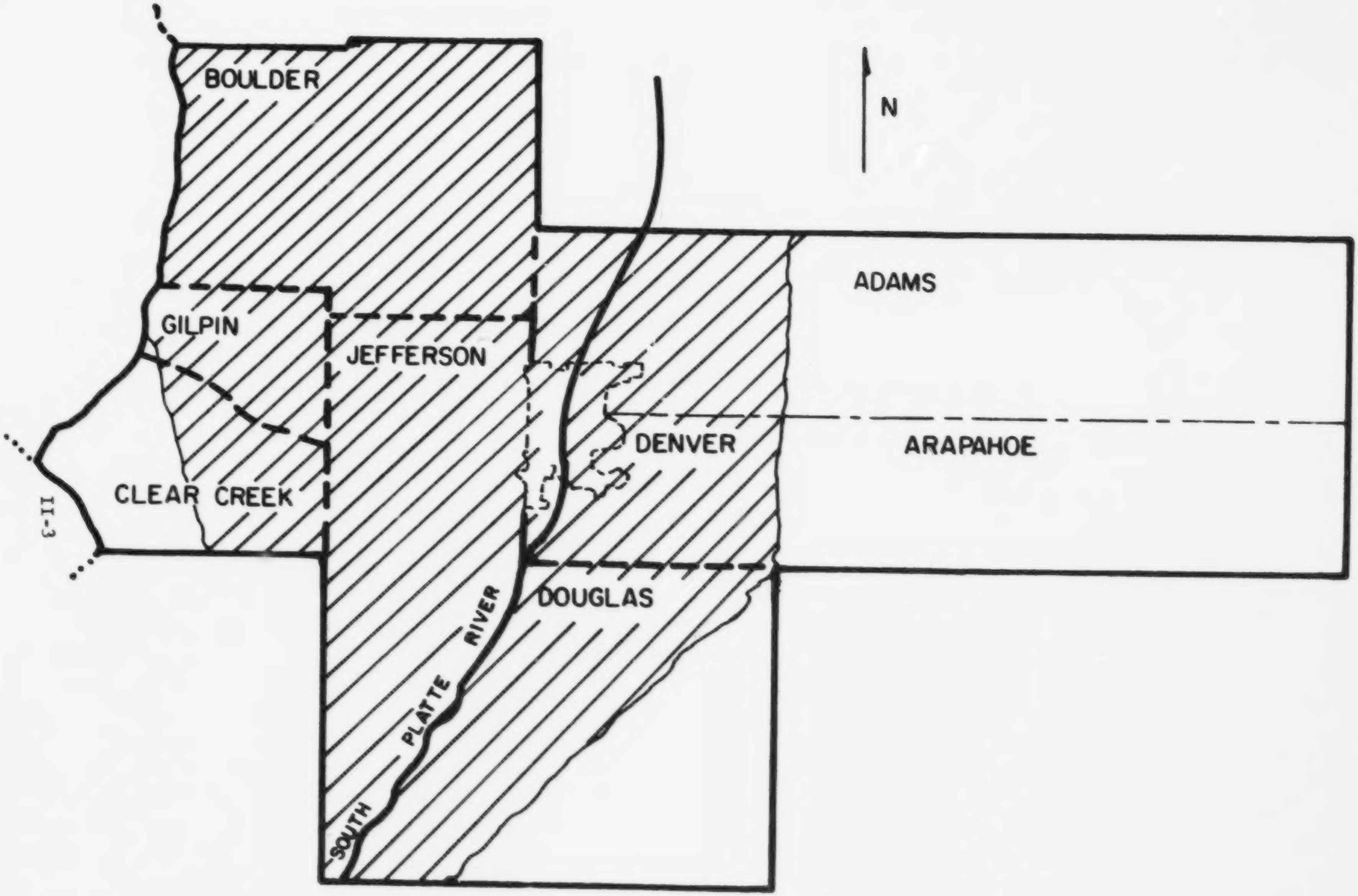

BOULDER
N
GILPIN
JEFFERSON
ADAMS
DENVER
ARAPAHOE
CLEAR CREEK
DOUGLAS
SOUTH PLATTE RIVER

Figure 2. Metropolitan Denver AQCR. Hatched area shows "Study Portion" of AQCR.

River drainage basin; as shown in Figure 2, the river flows from the southwest to the northeast through the center of Denver. Topographical details of the area are shown in Figure 3.

2. Climatology of the Region

The climates of local areas of Colorado are strongly influenced by differences in terrain and elevation, and by the orientation of mountain ranges and valleys relative to general air movements. Wide variations occur within short distances. For example, the difference in annual mean temperature between Pikes Peak and Las Animas (35°F), 90 miles to the southeast, is about the same as that between southern Florida and Iceland. As a second example, the average annual snowfall at Cumbres in the southern mountains is nearly 300 inches, while less than 30 miles away at Manassa in the San Luis Valley, snowfall averages less than 25 inches. As noted previously, the Metropolitan Denver AQCR extends from the mountain areas in the west to the beginnings of the eastern plains. The city of Denver itself is located within the eastern foothills of the Rockies. Summaries of the climatologies of these three zones follow:

Eastern Plains. From the eastern border of the AQCR westward to elevations of about 5,000 feet near the foothills, climatic conditions are similar to those of the Great Plains area in neighboring states. Winds are generally sufficiently strong and frequent to provide good ventilation and dispersion of air pollutants. Exceptions may be found along river valleys at times of low general air movement. Highly variable weather conditions results from incursions of cold dry air from the north, warm moist air from the Gulf of Mexico, and hot dry air from the southwest, into the prevailing westerly flow of relatively dry air from the mountains. Daily and seasonal ranges of temperature are large. Annual precipitation is low, usually less than 1/2 inch per month.

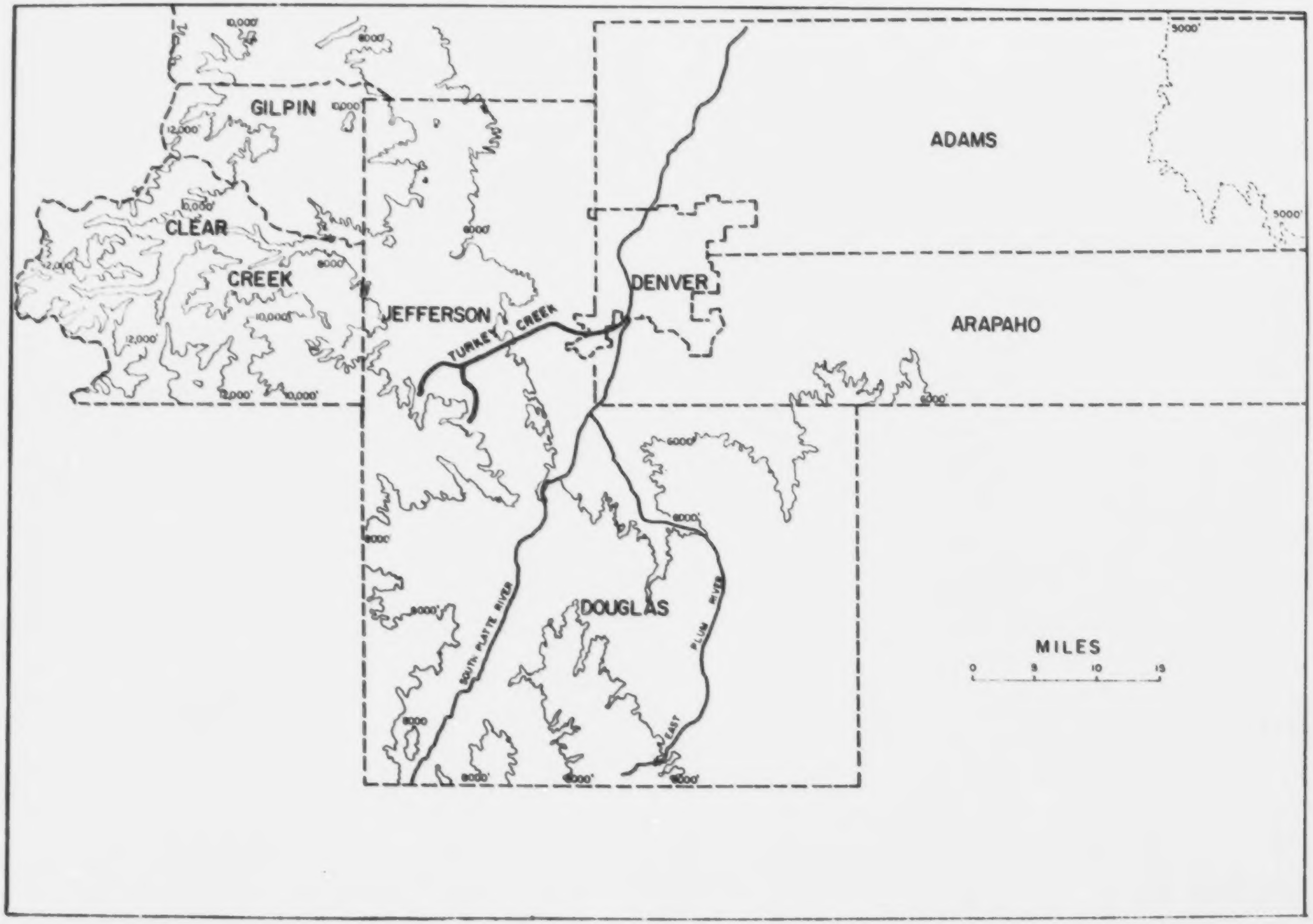

GILPIN
CLEAR
CREEK
JEFFERSON
TURKEY CREEK
DENVER
ADAMS
ARAPAHO
DOUGLAS
SOUTH PLATTE RIVER
PLUM RIVER
EAST
MILES
0
5
10
15
5000'
6000'
8000'
10,000'
12,000'

Figure 3. Topographic map of Denver region. Major contour lines are at 2,000 foot intervals

Other features are low average relative humidity, high percentage of sunshine, and low average cloudiness.

Eastern Foothills. This area is given a separate designation because its climate differs significantly from that of both the plains proper and the higher mountains in features of importance to air pollution problems. It extends from elevations near 5,000 feet on the plains up to 8,000 or 9,000 feet along the front ranges of mountains. One of the most significant differences is the reduction in average wind movement caused by the mountains to the west which shield the area from the prevailing westerly winds. Wide local variations in wind regimes are introduced into this area by the mountain and valley winds operating along the front ranges of hills. Air drainage is generally good in the canyons, but as these canyons emerge onto the plains the slope is much less, and the air circulation may become very sluggish along the wider river and creek valleys, resulting in a drastically increased pollution potential. Other climatic effects of the mountains on this area are reduced temperature variations and increased precipitation as compared to those of the plains proper. Table 1 gives the monthly, normal temperatures and precipitation amounts for Denver based on the thirty-year period from 1931 to 1960.

Mountain Areas. Mountain areas are those with elevations generally above 9,000 feet. The mountains present widely varying conditions of air circulation and ventilation, and of most other climatic factors. Ridges and mountain top areas, being exposed to the general air flow, are well ventilated by constant wind movement. Valleys and canyons, on the other hand, tend to be shielded from large scale wind movements; as a result, winds in these areas are largely controlled by local topographical and surface features and air pollution potential varies widely from place to place.

TABLE 1

MONTHLY NORMAL TEMPERATURES AND PRECIPITATION AMOUNTS AT DENVER (1931-1960)

Month	Temperature (deg F)	Precipitation (inches)
Jan.	29	0.6
Feb.	32	0.7
Mar.	36	1.2
Apr.	46	2.1
May	56	2.7
June	67	1.4
July	73	1.5
Aug.	72	1.3
Sept.	63	1.1
Oct.	51	1.0
Nov.	38	0.7
Dec.	32	0.5
	Total	14.8

3. Meteorology and Air Pollution

The degree of air pollution experienced by an area with approximately constant emission sources is primarily a function of meterological conditions. Specifically, the mean wind direction determines the direction toward which the pollutant cloud is transported, and the mean wind speed determines the travel time from the source to receptor. Also, as the speed of the air passing a pollution source increases, the volume or air diluting the pollutant increases, thus decreasing the downwind concentration of the pollutant. Furthermore, the rate of dilution, with respect to time or distance, is controlled by the small scale turbulent motions of the air, which vary with wind speed, surface roughness, and atmospheric stability.

The second most important meteorological index of pollution, after the wind flow, is usually the vertical stability of the atmosphere within the first few hundred meters of the earth's surface. This factor governs the ease with which pollutants can be mixed vertically, and the thickness of the atmospheric layer through which mixing occurs. It is determined by the rate at which the temperature of the atmosphere changes with altitude. When the temperature increases with altitude (an inversion condition) vertical movement of the air is inhibited and pollutants remain near the ground. On the other hand, when the temperature decreases rapidly with altitude, as is the usual midday condition near the earth's surface during fair weather, buoyancy encourages vertical motion and parcels of air move freely up and down for considerable distances. An example of the latter condition is the deep convective layer frequently made apparent by towering cumulonimbus clouds and thunderstorms. During a typical 24-hour cycle, the depth of the mixing layer in Denver varies by nearly one order of magnitude as a result of radiational cooling of the earth's surface at night and solar heating of the earth's surface during the day. The generally clear skies and low humidity of the area contributes markedly to the amplitude of this diurnal cycle.

The concentration of pollutants can also be influenced by precipitation through washout and by solar radiation through photochemical reactions.

Over relatively smooth, level terrain with uniform surface conditions, meteorological observations of mean wind and temperature may be representative of conditions over a large area. In other areas, this is not the case, and pronounced differences may occur within short distances. These differences are particularly marked during light wind conditions in irregular terrain, when wind flow patterns may be controlled by local mountain-valley wind systems. Air pollution and windflow patterns in the Denver AQCR have been studied and described over the past several years by Riehl (1962), Reiter (   ), Riehl and Herkop (1972), and others.

As shown in Figure 2, the South Platte River passes through the city of Denver, and under light nighttime wind conditions, surface air, made relatively more dense by radiational cooling, drains toward the bottom of the valley and northeastward toward lower elevations. According to Riehl and Herkop, the resulting shallow air mass, which has accumulated pollutants from city sources, is frequently brought back by a sudden wind reversal around noon. This reversal probably reflects upslope winds produced by surface heating during the morning. Toward evening the northward transport again becomes dominant.

Annual wind roses for 1970, prepared from data collected at three stations in the Metro Denver AQCR, were presented in the State Implementation Plan. The locations of the wind stations are indicated in Figure 4, while the wind roses are shown in Figure 5. The influence of the nighttime drainage winds on airflow in Denver and along the river valley is shown by the high frequency of southerly and south-southwesterly winds at all three stations. The daytime upslope winds are frequently limited to the period from midday to early evening and hence are less apparent in the wind roses for the Denver

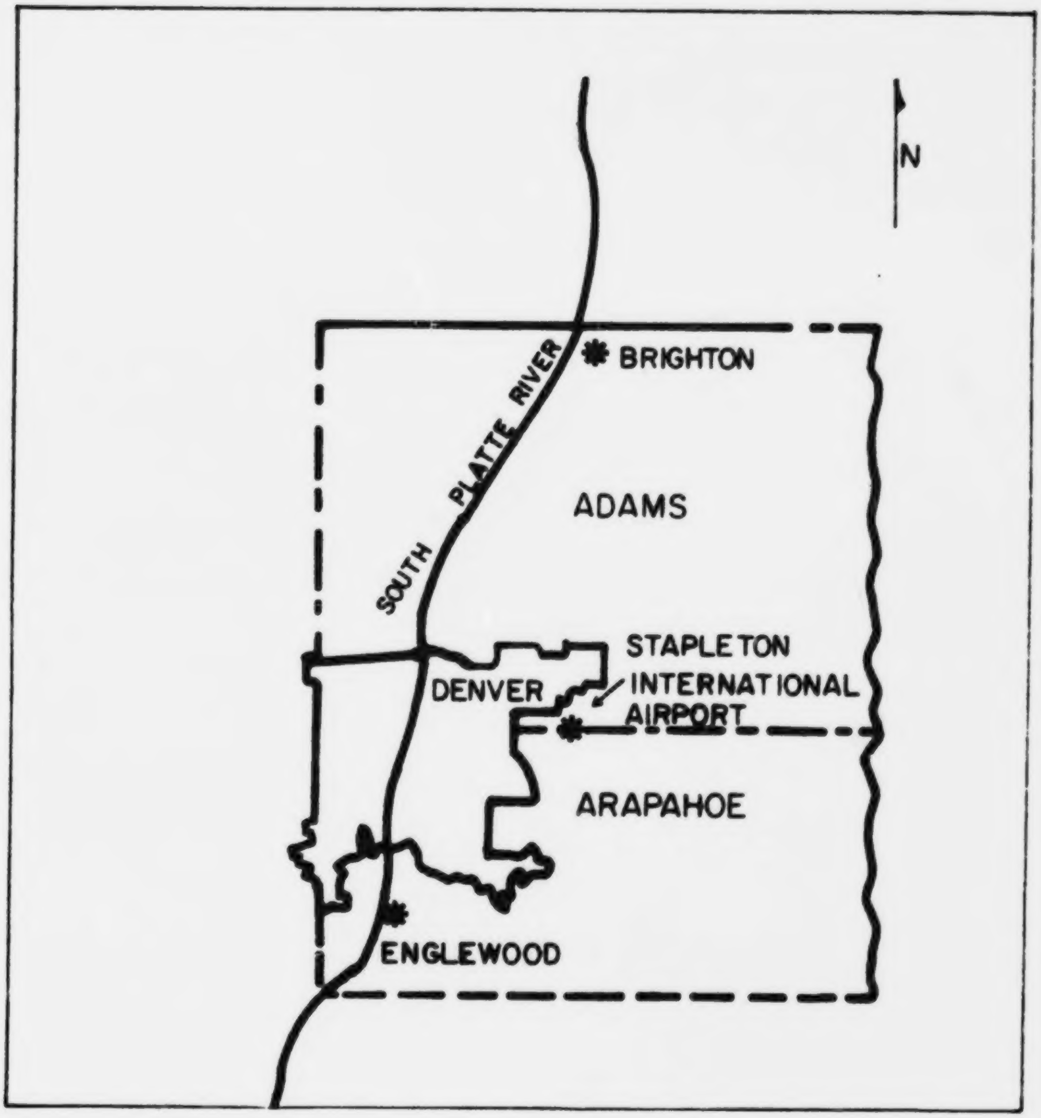

N
BRIGHTON
SOUTH PLATTE RIVER
ADAMS
STAPLETON
INTERNATIONAL
AIRPORT
DENVER
ARAPAHOE
ENGLEWOOD

Figure 4. Map showing three wind stations used in calculating annual wind roses. Location of station is indicated by the symbol ✱.

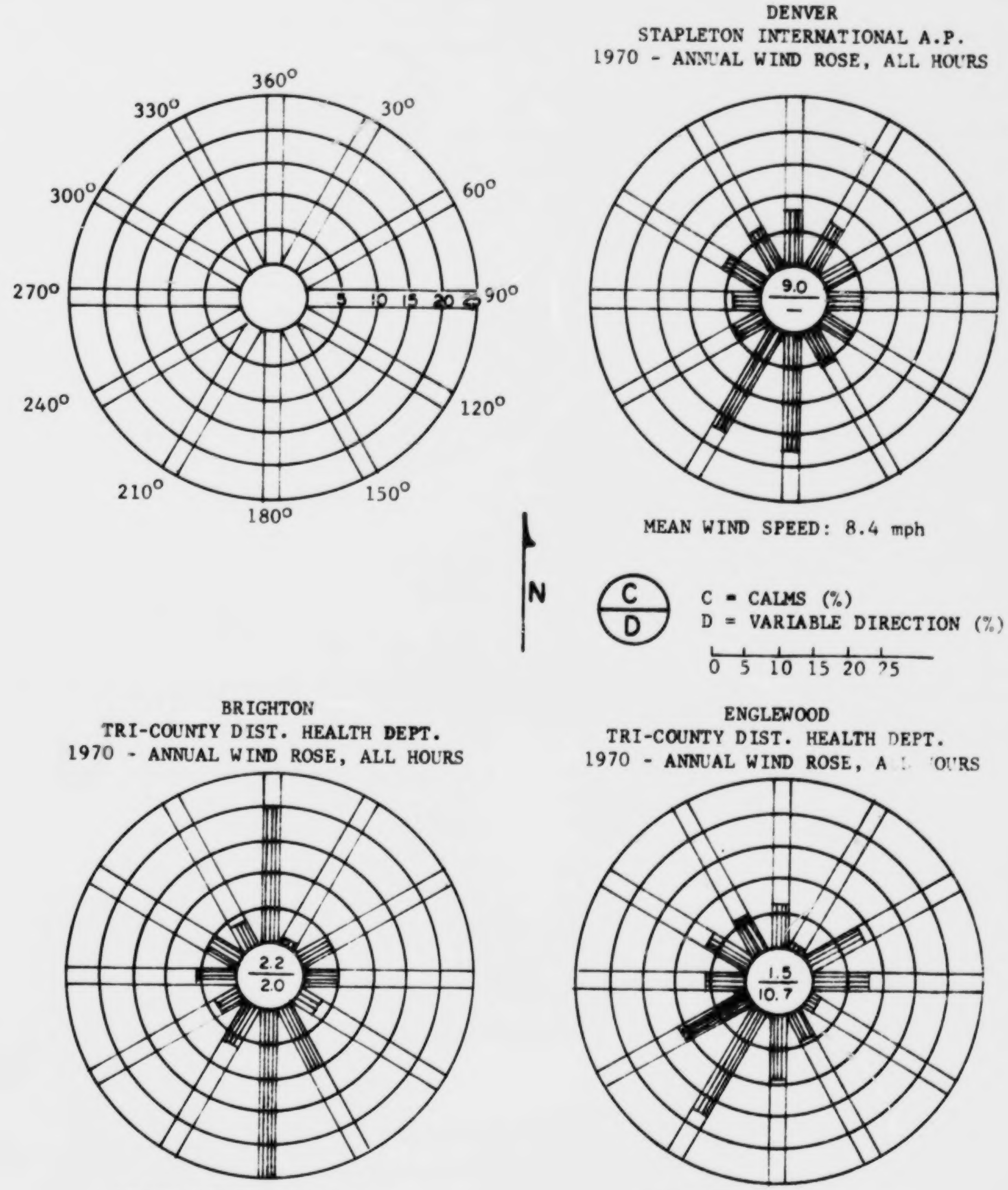


Figure 5. 1970 Wind roses for three locations in the study area

airport and Englewood. However at Brighton, 20 miles northeast of downtown Denver, north winds were observed nearly 19 percent of the time. This high frequency of northerly winds apparently reflects the proximity of the wind sensor to the river valley and perhaps the influence of the Denver urban heat island.

As explained previously, an inversion layer in the atmosphere is a layer through which the temperature increases with altitude and within which vertical motions are suppressed. The inversion may be ground-based, trapping pollutants near ground level, or it may occur at some appreciable height above ground where it serves as a lid to the mixing layer. On most nights of the year in the Denver area, temperature inversions form at or near the surface; these inversions range from a few degrees to 30°F or more in extreme cases. In Table 2, the frequency of low-level inversions in Denver is given by season for four times of the day. The high frequency of early morning inversions in summer (84 percent at 5 a.m.) is not necessarily associated with high pollution levels, since daytime heating rapidly breaks up the inversion as shown by the reduction in frequency to 15 percent by 8 a.m.

The maximum vertical depth of the atmosphere available in any day for the mixing of polluted air usually occurs in the afternoon following the period of maximum surface heating and is known as the maximum mixing height. The minimum mixing height is associated with minimum surface temperatures and usually occurs at or around sunrise. For any given wind speed, the greater the mixing height, the greater the volume of air available to dilute the pollutants and therefore to lower their concentrations. For the Denver region, afternoon mixing heights are greatest in the spring and summer and least in the fall and winter. Table 3 shows the monthly variation of morning and afternoon mixing heights, based on an 8-year period. The mean morning mixing heights

TABLE 2

PERCENT FREQUENCY OF LOW-LEVEL INVERSION*

Stapleton International Airport

Season	5 p.m.	8 p.m.	5 p.m.	8 a.m.
Fall	22	78	80	49
Winter	54	82	83	75
Spring	5	58	65	22
Summer	8	54	84	15

* Hosler, Charles R., 1961: Low-level inversion frequency in the Contiguous United States. Monthly Weather Review, vol. 89, Sept., 1961, 319-339.

TABLE 3

DENVER - STAPLETON INTERNATIONAL AIRPORT

Morning and Afternoon
Mixing Height (Meters)

	8-year average 1960-67	
Month	Morning	Afternoon
January	189	1472
February	239	1765
March	376	2496
April	438	2939
May	377	3590
June	360	2907
July	244	3312
August	283	3140
September	243	2746
October	175	2369
November	226	1642
December	259	1290

range from about 175 to 450 meters, with the greatest heights occurring in the spring and early summer. The mean afternoon mixing heights show a pronounced seasonal variation, from about 1300 meters in December to 3600 meters in May. The monthly variations of the mixing heights are shown graphically in Figure 6.

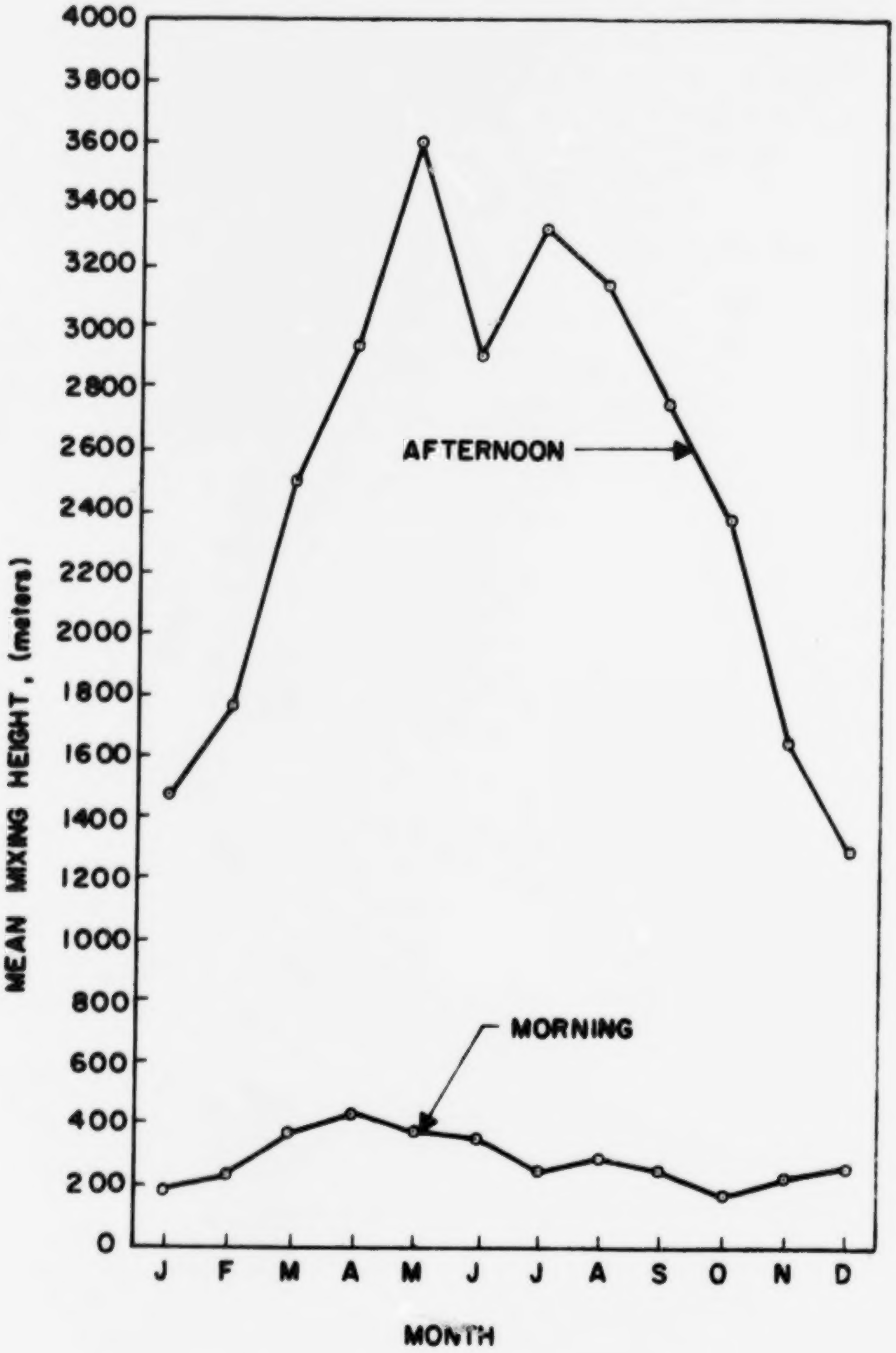


Figure 6. Monthly mean mixing heights at Denver, Colorado based on an 8-year period

4. Hydrology

The Denver metropolitan area lies within the South Platte River Basin. The Basin is characterized in the west by the eastern slopes of the Rocky Mountains and in the east by the plains. The South Platte River, which flows through the metropolitan area from southwest to northeast, originates in the eastern slope of the Rockies and is feed by snowmelt, rainfall runoff, groundwater and a number of man controlled factors such as sewage treatment plant effluents and trans-mountain diversion. In 1970, trans-mountain water diversion was 300,500 acre-feet; this diversion is to be increased to 559,000 acre-feet by the year 2010. This trans-mountain diverted water affects the hydrology of the South Platte River Basin through its discharge into the South Platte River after its use for municipal and industrial purposes. Also, its use for lawn sprinkling affects the hydrology of the Basin through recharge of groundwater which feeds many creeks.

Although the Basin only receives an annual average of 14.8 inches of rainfall, flooding is a fairly common occurrence, with the most recent floods occurring in 1965 and 1973. Snowmelt, runoff, and interval rainstorms are a predominant cause of flooding. Also, urbanization within the Denver Metropolitan Area, with its resulting increase in impervious area, increases the peak and volume of floods and increases the probability of flash floods. The Chatfield Dam on the South Platte and the Cherry Creek Reservoir have been constructed to decrease the intensity and frequency of flooding.

Influenced by regional factors, the South Platte River experiences a wide range of flows. Sewage treatment plant effluents from Denver and a few smaller communities contribute to the flow of the South Platte and become a predominant fraction of the flow during low flow conditions.

The western portion of the Basin is tapped for water supply and in 1970 delivered 146,000 acre-feet which will increase to 223,800 acre-feet by the year 2010. Once water reaches the main stem of the South Platte its major uses are for industrial (e.g. cooling), and irrigation purposes.

5. Land Use

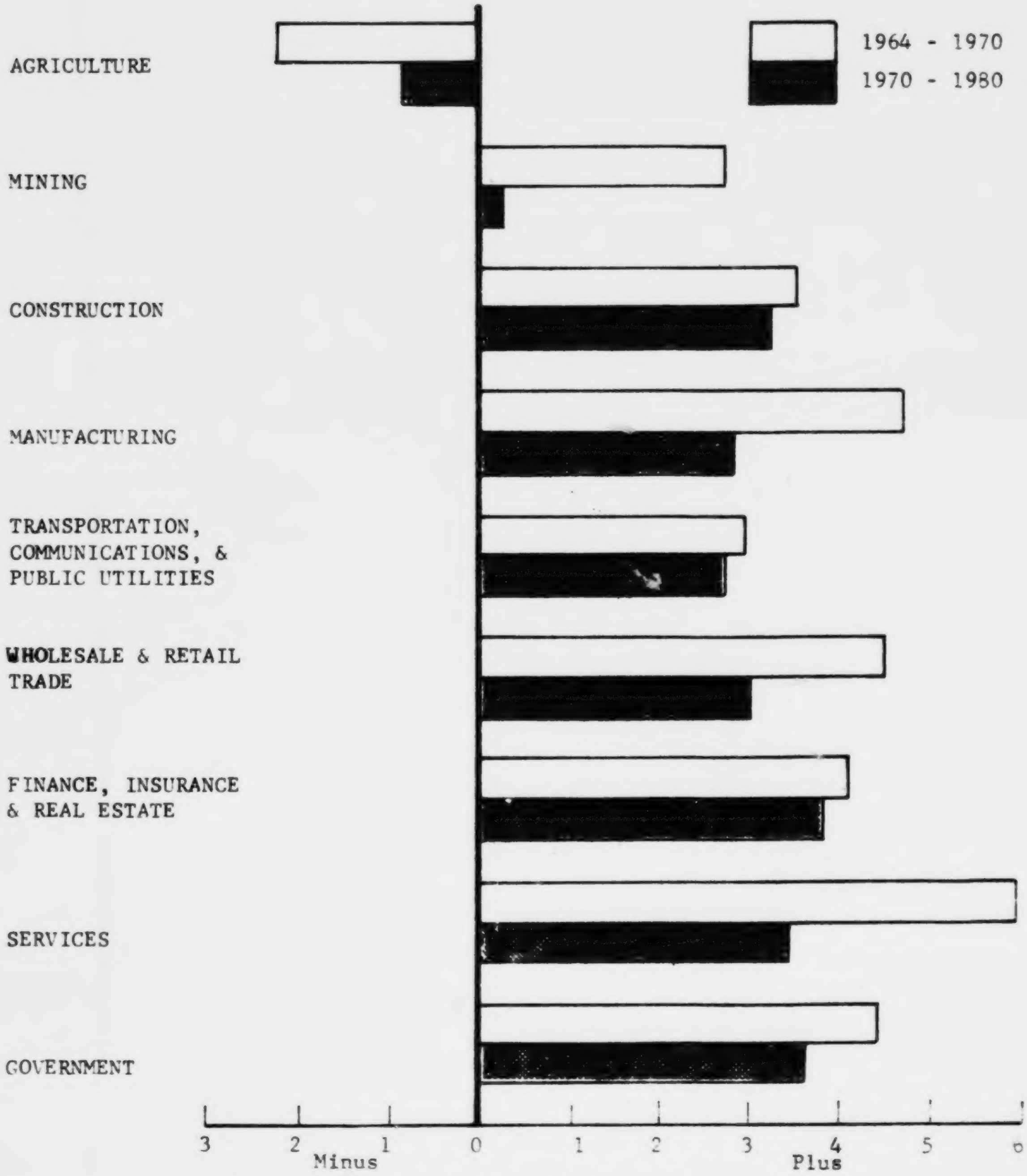
The distribution of land uses in the study area today is the result of a large number of regional characteristics, very significant among which are the transportation network and infrastructure. Land use changes in Colorado parallel natural trends, showing an increase in urban land while agricultural land has declined.

The Transportation Control Plan Study Area encompasses parts or all of eight counties (Figure 2) which comprise the Metropolitan Denver AQCR. The Denver AQCR covers a land area of 5045 square miles, centered around the Denver Metropolitan Area, occupying about 275 square miles, and Denver's center city occupying approximately two square miles including a Central Business District (CBD) of 350 acres. General land use trends for the Denver Standard Metropolitan Statistical Area (SMSA) show agricultural and vacant land being transformed to single-family residential use. Major portions of the urbanized areas in the Study Area are characterized by single-family tract housing, strip commercial developments and a substantial freeway network. The recent decades have shown circumferential development in all directions from the Denver Metropolitan Area, served by upgraded arterials and new highways. The influence of transportation on land use choices interact through one or more of the following factors: site opportunities for development; population density; accessibility of facilities, services, employment, and community amenities; travel time requirements and costs. Generally, for the Denver region, land use patterns have developed in response to the automobile. Nevertheless, the center of Denver, near the State Capitol, creates one of several high intensity development areas within the City. Others are focused on universities, Federal employment areas, and shopping districts. The major characteristic of the region, however, is its low growth density and dispersed development pattern.

A recent inventory of zoning in the Denver SMSA shows 19 percent or nearly one-fifth of the land zoned for residential use. Although 61 percent of the land in the region is still zoned for agriculture, the trend is for rezoning to higher use (residential, commercial, industrial, and recreational), with the Transportation Study Plan Area being concentrated in the Denver, Boulder, Golden and Longmont urbanized areas. Figure 7 illustrates the existing and projected change in economic activities by various land use/employment types for the Denver region.

The distribution of land uses in the Denver CBD and urbanized regions of the study area reflects the governmental, financial, service, and distribution functions that the urban centers perform for the metropolitan area and the larger Rocky Mountain region. Downtown

Figure 7: Annual Growth Rates for Economic Activity showing land use Development Potential, Denver Region (*)



* Source: Denver Region Council of Governments

Denver is not a manufacturing center, but rather the keystone of business and government, devoted to the distribution and exchange of goods, money and ideas. In decreasing order of importance, office space, hotels and motels, retail activity, and governmental facilities are the primary land uses in the Denver CBD, followed by residential, storage, commercial services, and industrial uses.

For the Denver SMSA, as a whole, commercial and industrial land uses have developed in a dispersion pattern around the urban centers. Commercial growth is mainly attributable to the development of various neighborhood, and regional shopping centers. There has been a continued dispersion of new industrial development, while diverse changes are evident in the services, parks and public land uses. New development and growth potential will depend upon available vacant space, transportation accessibility, costs, availability of water resources and related factors. Land use planning and zoning activities have varied in the region's areas. Denver and Aurora, for example, have aggessive annexation policies and promote higher use development of vacant lands through their zoning regulations. Figures 8 and 9 illustrate the 1970 and projected 1980 land use development densities, thereby mapping the pattern of change and areas with growth potential.

In the longer term, environmental quality will be enhanced by improved land use planning and a balanced transportation system that will be able to satisfy the divergent travel demands of the region. The State of Colorado has established statewide land use and transportation agencies to provide for control of overall regional develop-

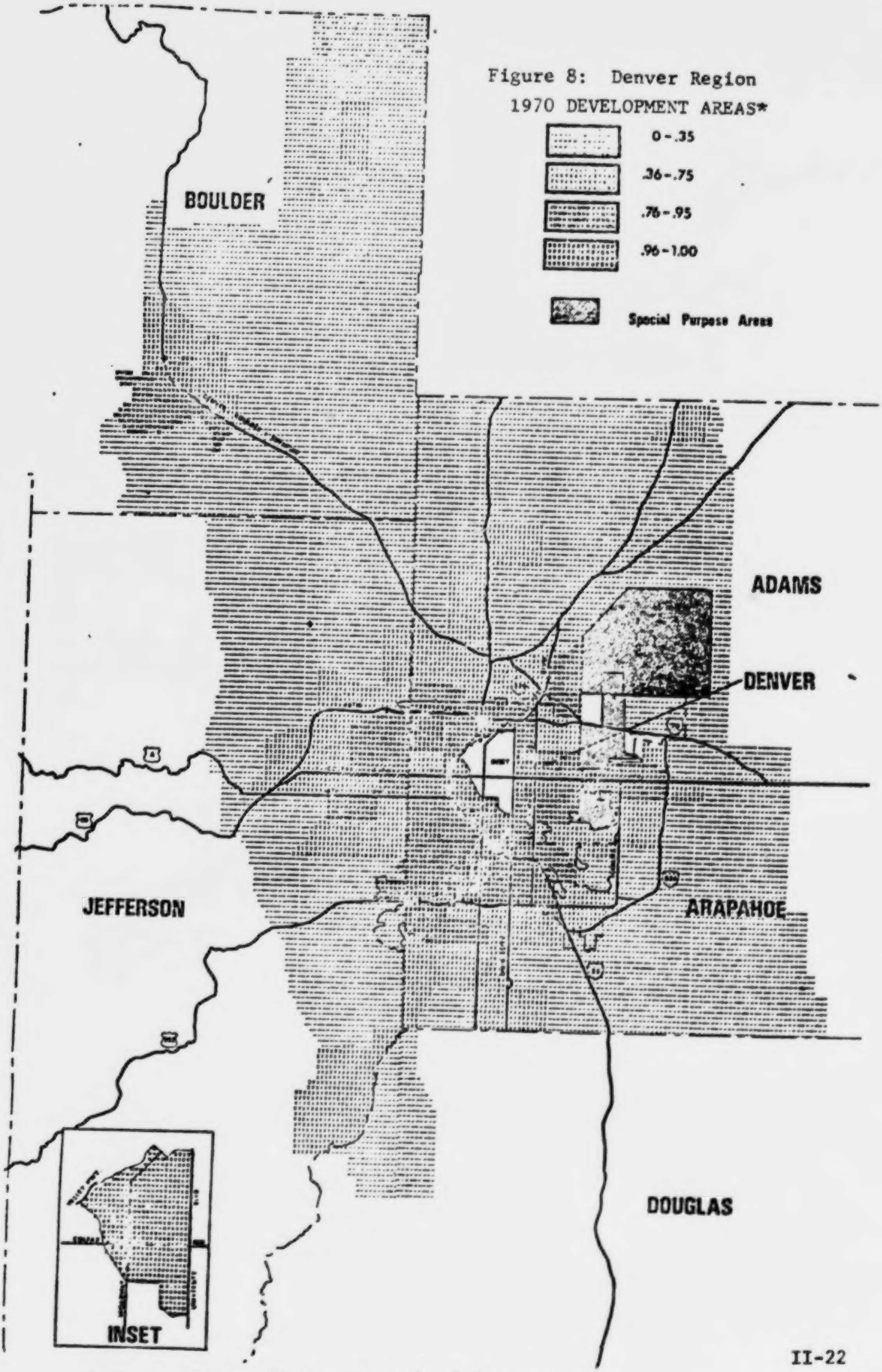


Figure 8: Denver Region
1970 DEVELOPMENT AREAS*

0 - .35
.36 - .75
.76 - .95
.96 - 1.00
Special Purpose Areas
BOULDER
ADAMS
DENVER
JEFFERSON
ARAPAHOE
DOUGLAS
INSET

*Source: Denver Region Council of Governments

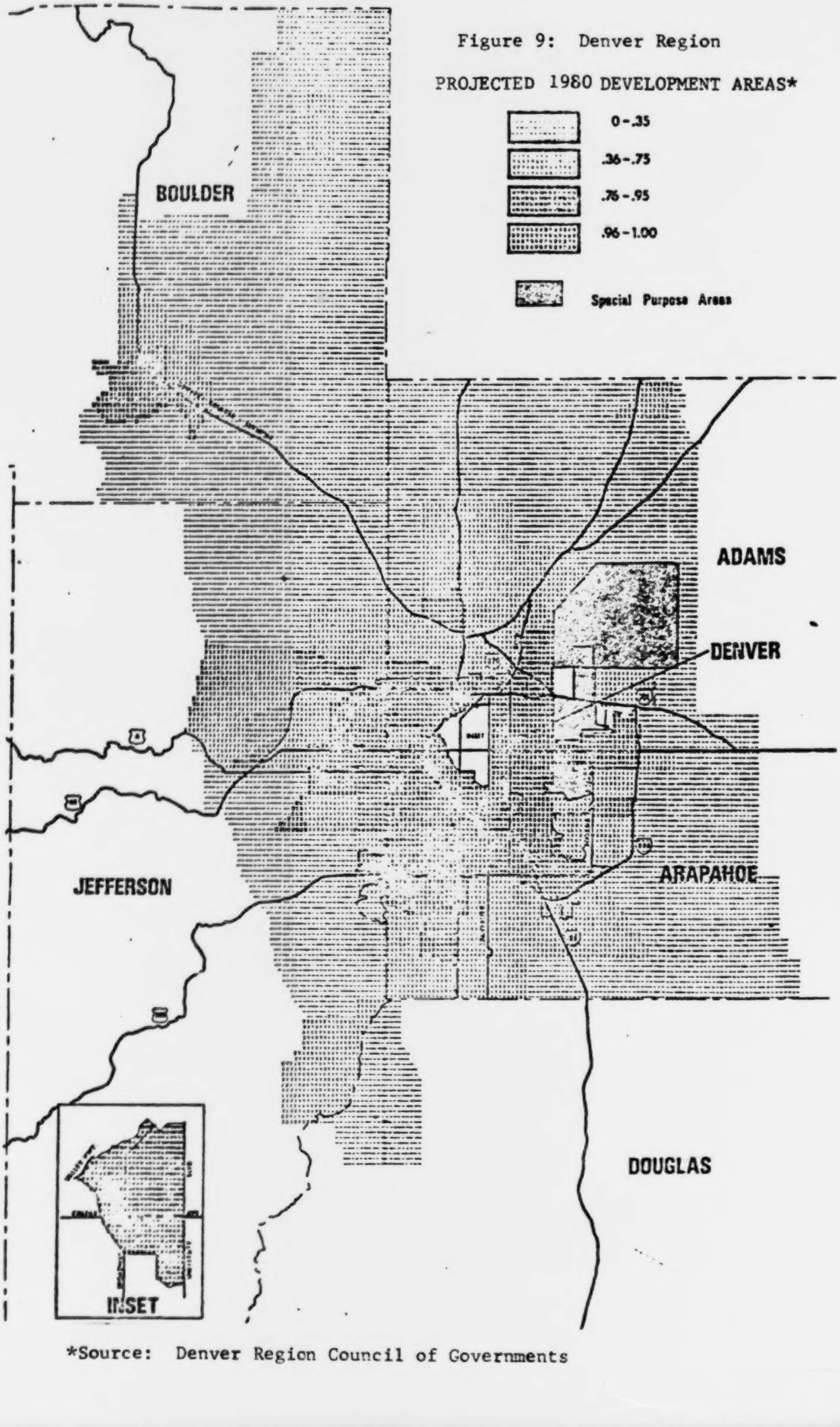


Figure 9: Denver Region

PROJECTED 1980 DEVELOPMENT AREAS*

0 - .35
.36 - .75
.76 - .95
.96 - 1.00
Special Purpose Areas
BOULDER
ADAMS
DENVER
ARAPAHOE
JEFFERSON
DOUGLAS
INSET

*Source: Denver Region Council of Governments

ment to meet environmental quality objectives, with transportation systems responding to, rather than directing, land use planning.

6. Transportation Infrastructure and Use

Transportation demand is influenced by many aspects of urban growth and land use in the Denver Region and the transportation system, in turn, influences the character of regional growth. Presently in the Denver AQCR, and Transportation Control Plan Study Area thereof, the automobile is the dominant mode of travel. A history of auto-dominance in the region has been accompanied by the construction of a large highway system comprised of urban freeways and major arteries traversing the metropolitan region.

Summarizing the transportation facilities and public utilities, the Denver SMSA is served by eleven major highways, five major railroads, and eleven interstate airlines. The area also encompasses six airports for general aviation, and one military airport. Numerous interstate and intrastate bus lines serve the area, and the ratio of automobiles to persons is one of the highest in the country - one automobile for every 1.5 persons in the state. A regional public mass transportation system is currently being designed for the Denver region.

The Denver metropolitan area is characterized by a high growth rate of motor vehicles (5.2 percent per year) and the highest per capita automobile registration in the nation. On an average day in 1972 approximately 15 million vehicle miles of travel were produced in the Denver urbanized area. This has been estimated to increase about 18 million VMT in 1980 by the Colorado Highway Department.

Figure 10 A-D illustrates the relative growth history of several automobile related characteristics compared to Denver regional population growth.

In the Denver SMSA the following characteristics apply:

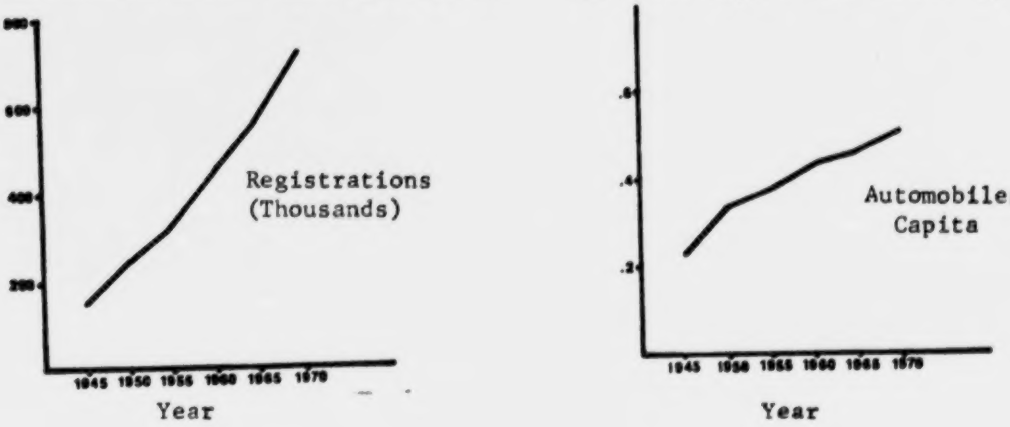
Population (1970):	1,227,529
(1973):	1,416,800
Automobiles & Taxis (1971):	651,000
Trucks & Buses (1971):	195,000
Total number of vehicles (1971):	861,000
Driver's licensed (1970):	767,000

On an average, automobile occupancy in commuter cars is estimated to be 1.3 - 1.6 person/car. In 1971 the Colorado Highway Department conducted an origin-destination transportation survey in the Denver region (Denver County and portions of Adams, Arapaho and Jefferson Counties) to determine the number of trips, mode of travel and trip purpose for residents in the Denver region. The sample size included 1/30 of all residents listed on the State Public Service (utilities) listing. Tables 4 and 5 show results of this survey.

Bus transit, the primary intra-region mass transit service in the Denver region, is now only used by a small portion of the region's population. Estimates range from 2-5 percent of all trips in the Denver region are presently accounted for by the bus system. Since a normal bus has seats for 45 to 50 people, one full bus can replace from 30 to 35 automobiles.

Figure 10: Transportation Usage in the Denver Region

10A: Passenger Automobile Registration 10B: Per Capita Automobile Registration



10C: Total Daily Colorado Vehicle Miles 10D: Daily per Capita Vehicle Miles Colorado

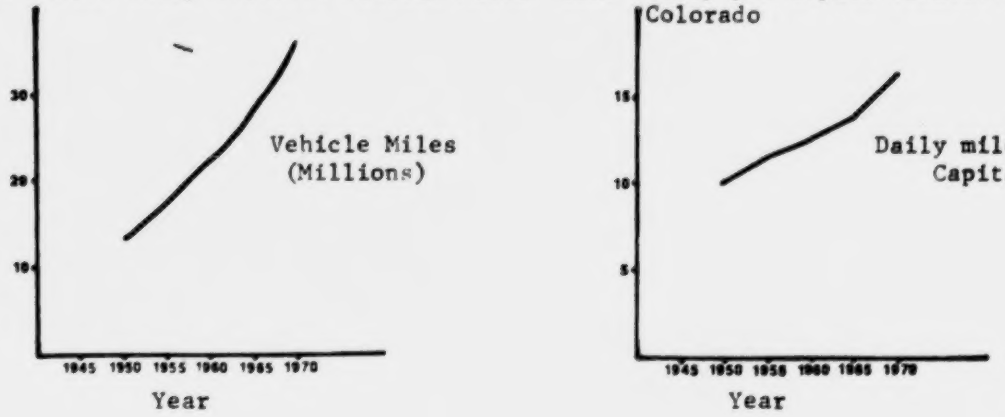


TABLE 4

Transit Trips in the Denver Region:

Vehicle Type	Number of Trips	Percent of Total Trips
Automobile	2,885,098	86
Trucks	84,535	12
Transit (including taxi)	21,258	2
TOTAL	3,463,268	100

TABLE 5

Distribution of Automobile Trips by Purpose of Trip*

Trip Purpose	Number of Trips	Percent of Total Trips
Work	946,983	31.7
Social-Recreational	802,356	26.8
Shopping	643,222	21.5
Personal Business (including home, serve passenger, change passenger mode)	497,756	16.6
School	100,514	3.4
TOTAL	2,990,891	100.0

*Includes both home-based and Non-home based trips

In 1969 the State of Colorado created legislation establishing a Regional Transportation District, charged with developing long-range highway and mass transit plans for transportation to serve the seven-county Denver region. A regional transportation plan was subsequently developed for the seven-county District (Denver, Adams, Arapaho, Douglas, Jefferson, Boulder and Weld). The proposed system consists of a coordinated combination of several kinds of public transit throughout the region, including a Personal Rapid Transit (PRT) rail system, local bus, express bus, and regional bus service. Public acceptance of the proposed RTD $1.6 billion plan was demonstrated on 7 September 1973, in a public referendum approving a sales tax to finance the plan.

The two primary elements of the RTD transit plan include an "Early Action Program" (EAP) interim component and a 100 mile network of guideway "Personal Rapid Transit" routes in the most heavily traveled areas of Denver, Boulder and Greeley to be completed by 1984. The Early Action Program, relying on bus service, is planned to provide improved transit service at the earliest possible date following the successful 7 September referendum, by adding new routes and increasing the frequency on existing routes. In addition to acquiring the existing Denver Metro Transit bus system, 115 new buses will be purchased. The EAP is proposed to provide an increase of about 270 route miles within the district, representing an increase of about 60 percent in bus service. Daily bus miles will increase by some 33 percent, to about 32,000 miles.

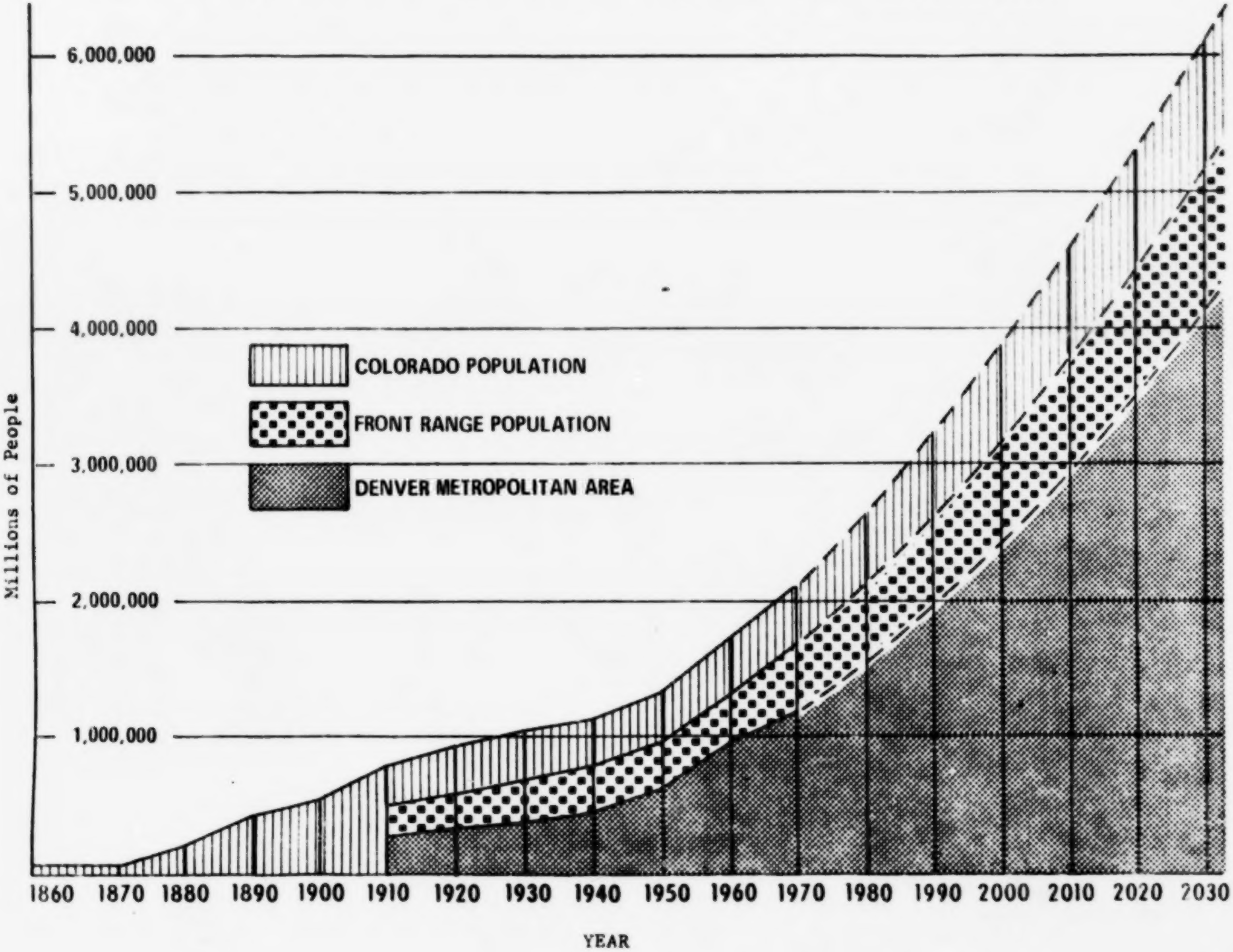
B. SOCIO-ECONOMIC DESCRIPTION

1. Population

Colorado is ranked as one of the 10 fastest growing states in the nation, with a statewide population increase of 25.8 percent in the 1960-1970 decade (annual growth of 2.3 percent). The Denver region's population has grown at a faster pace in the past three decades, ranging from 3 to 4.6 percent per year, with over one-half of Colorado's total population residing in the five county Denver SMSA. The Denver SMSA, encompassing Adams, Arapahoe, Boulder, Denver and Jefferson Counties had a 1970 population of 1,227,529. Based on population gains through mid-1973, the Denver Region Council of Governments (DRCOG) estimates the current SMSA population to be approximately 1,416,800.

Denver County contained over 50 percent of the total metropolitan population in 1960, however, it is estimated that by the year 2000 it will only retain about 25 percent of the total. Population is decreasing in the central city as urban sprawl moves to the north and south along the front range. The suburban communities accounted for approximately 80 percent of the area's population increase between 1950 and 1970. Based on estimates of the Colorado State Planning Office, Figure 11 shows the proportion of the Colorado population increase expected to be attributable to the Denver Metropolitan area and the Colorado Front Range Corridor east of the Rocky Mountains from Wyoming to New Mexico through the year 2000. While the Front Range area and metropolitan Denver are projected to experience explosive growth, the rest of the state's population may stabilize or decline.

Figure 11: Present and Projected Population of Colorado and the Denver Metropolitan Area*



*Based on figures developed by the Colorado State Planning Office

The major components of population change for the Denver urbanized area include natural increase through increased births, and net migration. Of the two, net migration, or the difference between those coming into the area and those leaving has been the most important. Currently, approximately 80 percent of the region's growth is attributable to net in-migration. Both rural-urban migration and the relative stability of Denver's economy are cited as primary contributing factors for the large influx of the residents.

Density of population in the Denver central city, in 1970, was 7,602 per square mile and 198 beyond the central city. In general this is a low suburban density and is partially because Denver is relatively isolated from other major cities. Additionally, people have shown a preference for open space in the metropolitan area, supported by the high mobility afforded by the automotive dominant transportation system and extensive highway network. The overriding characteristic of the region is this low population density and dispersed growth pattern.

2. Housing

The Denver SMSA has a strong single-family housing structure tradition, with single family homes comprising from 65 percent of all housing units in Denver County to 88 percent in Adams County in 1970, or an urbanized area average of 75 percent. Projections of housing stock for Denver indicate that single family homes will continue to capture approximately half the new housing units with an increased trend toward low-rise, multiple unit complexes and cluster type developments. This development breakdown is sensitive to a wide-range of economic, social, and service related factors including transportation accessibility.

Low density, dispersed residential development patterns characterizing the regions are expected to continue with circumferential growth occurring from city centers and radial growth along transportation corridors. Other housing trends such as a declining number of persons per housing unit and popularity of low density residences are expected to continue based on existing trends, economic forces and social attitudes.

3. Employment

The Denver region has shown relatively healthy economic performance in the past decade, with total employment in the region increasing by 30 percent between 1964 and 1970. This represents an annual compound growth rate of 4.5 percent per year. The 1970 labor force for the area was approximately 550,000, with 26,000 employed by the Federal Government.

Based on analysis of industrial groups and employment trends the Denver Region Council of Governments (DRCOG) has projected employment growth trends by industry group to the year 2000. Figure 12 displays the present industrial group employment mix and projected growth trends by DRCOG. Table 6 provides the forccasted annual rates of employment growth for the Denver Regions by industrial type. These employment growth projections show that higher that average total employment growth will be experienced by three industries: 1) finance,

Figure 12: Present and Projected Employment by Industry Group in the Denver Region

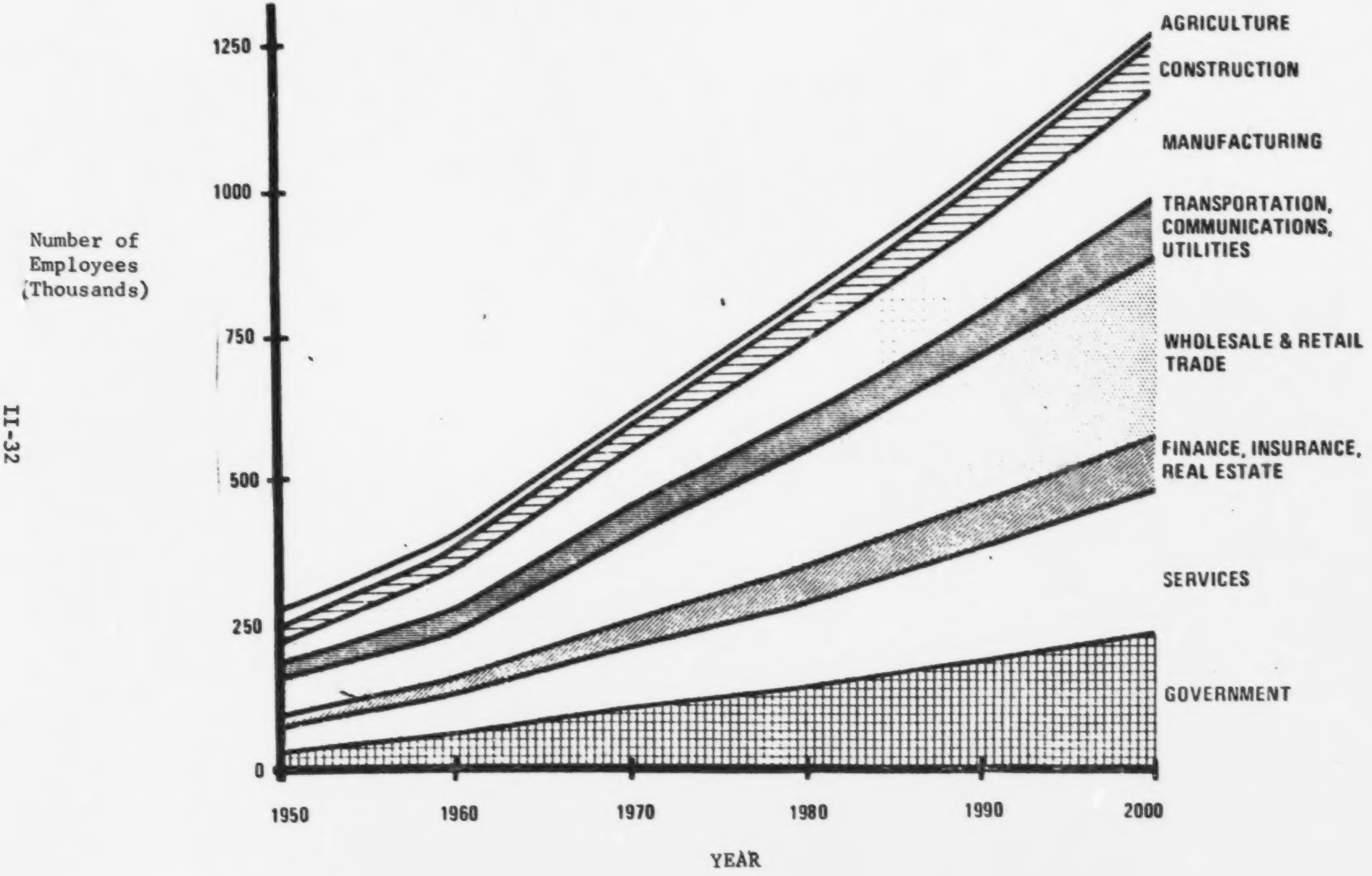


TABLE 6

Forecast annual rates of employment growth, Denver region, 1970-2000

INDUSTRY CATEGORY	FORECAST ANNUAL RATE OF GROWTH		
	1970-80	1980-90	1990-2000
Agriculture	-0.8%	-1.1%	-1.6%
Mining	0.2	0.4	0.4
Contract Construction	3.2	2.4	1.9
Manufacturing	2.8	2.2	1.7
Transportation, Communication and Public Utilities	2.7	2.7	1.6
Wholesale and Retail Trade	3.0	2.3	1.8
Finance, Insurance and Real Estate	3.8	2.8	2.1
Services	3.4	2.6	2.2
Government	3.6	2.7	2.4
TOTAL	3.1%	2.4%	2.0%

insurance and real estate, 2) services, and 3) government. Approximately average growth will occur in two industries: 1) construction, and 2) wholesale and retail trade. Employment growth rates of two industrial groups will be consistently below the rate of growth in total employment: 1) manufacturing, and 2) transportation, communications and utilities. One industry, agriculture, however, is projected to have a negative growth rate.

Approximately two thirds of the employment growth between 1964 and 1970 occurred in Denver County, while about 95 percent of the population growth was in surrounding counties. This indicates an inward work trip transportation flow for the region. Figures 13 and 14 show the 1970 and projected 1980 employment density mapping for the Denver region. The density pattern illustrates that employment will not disperse significantly through the region, but will continue to be concentrated in the core region, thus requiring continued commuter traffic. Some services have followed the residential development in the suburbs, but as yet, no clear proliferation of industrial development is apparent.

Based on a census week in 1970, only 4.2 percent of the workers in the Denver SMSA traveled to work on public transportation. The majority of the workers, 74.8 percent drove private automobiles while 10.4 percent were passengers in private autos, and 8.5 percent walked to or from their place or work. Table 7 summarizes this census data on means of transportation to place of work.

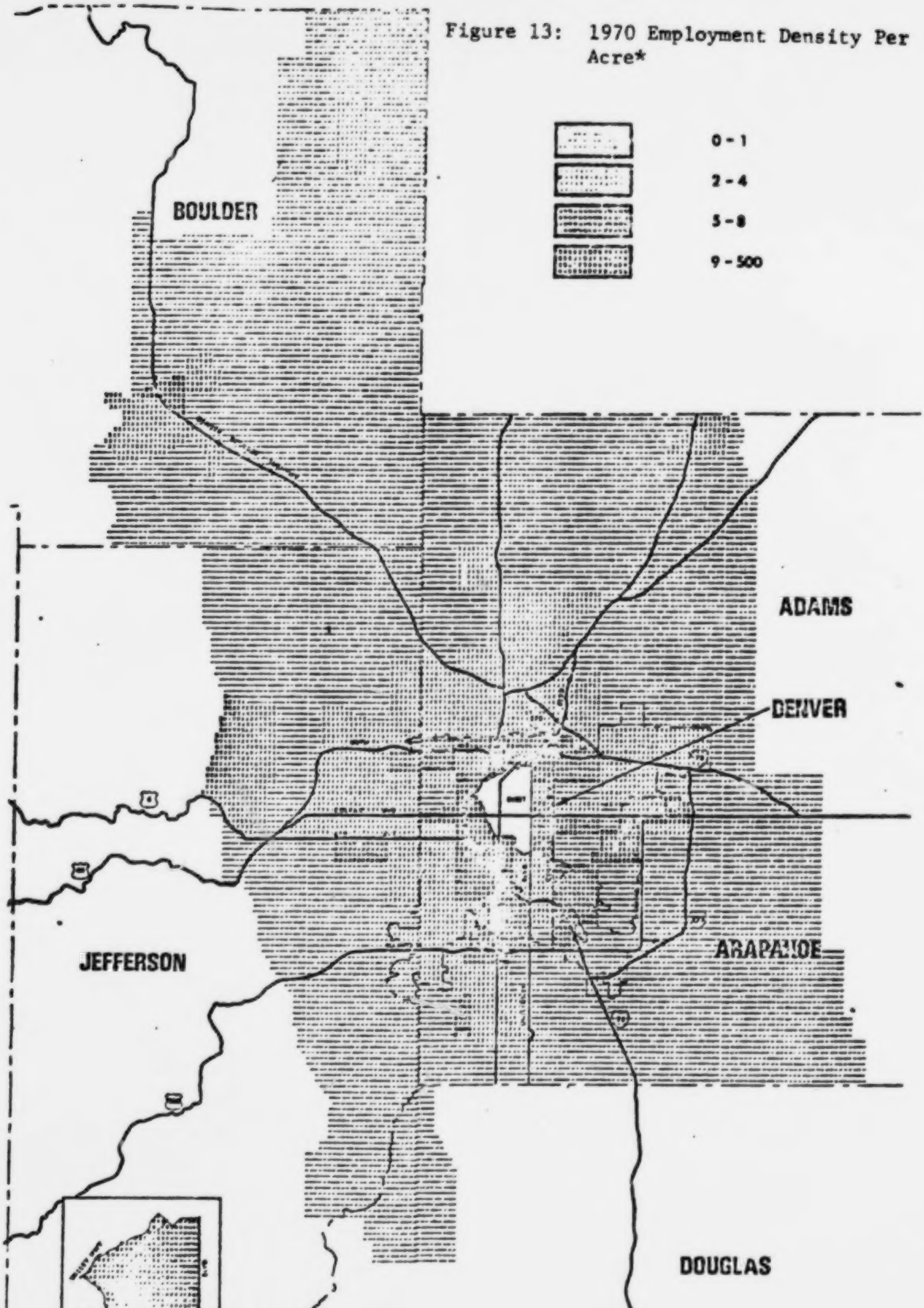
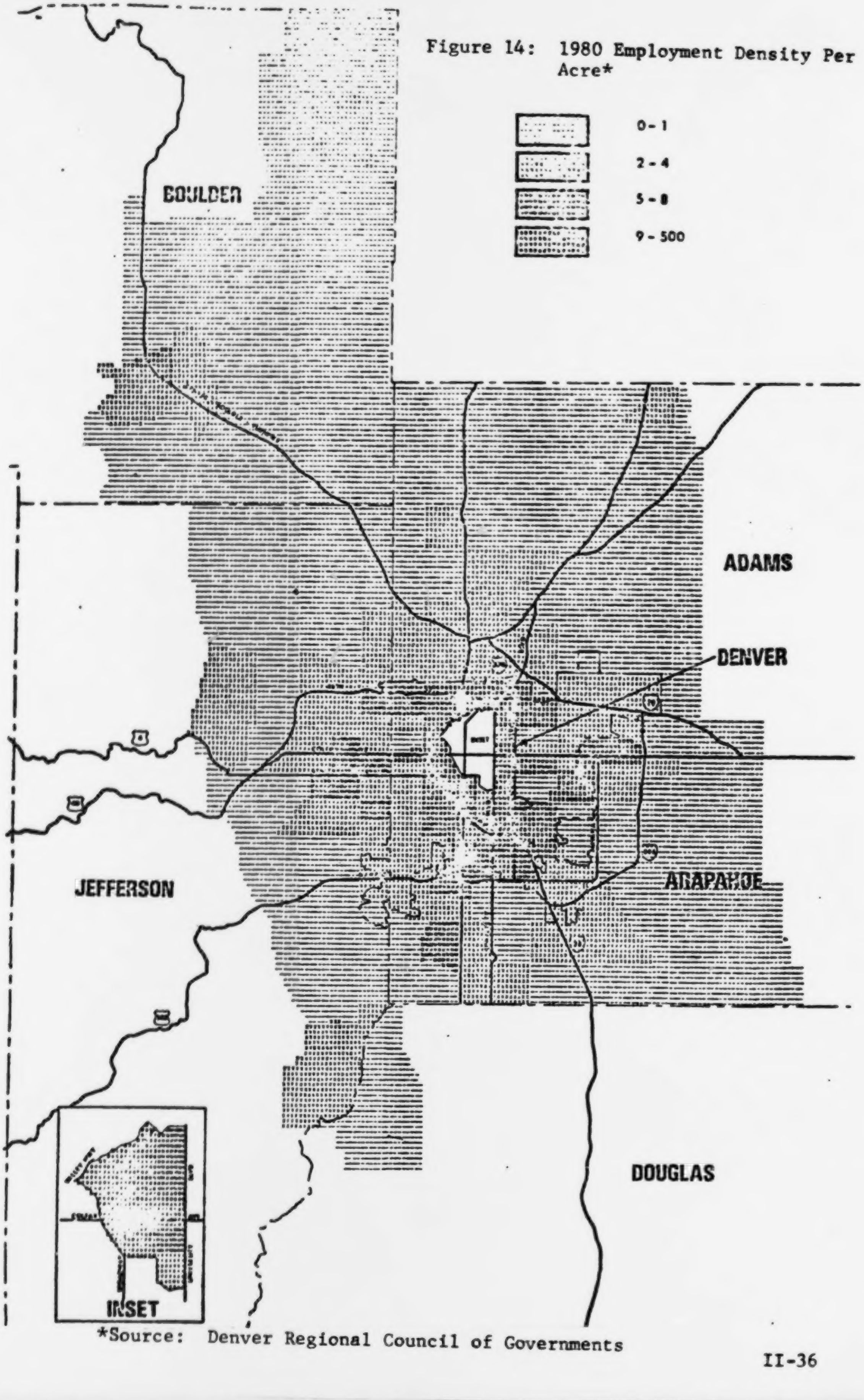

0 - 1
2 - 4
5 - 8
9 - 500
BOULDER
ADAMS
DENVER
JEFFERSON
ARAPAHOE
DOUGLAS
INSET

Figure 13: 1970 Employment Density Per Acre*

*Source: Denver Region Council of Governments

Figure 14: 1980 Employment Density Per Acre*


0 - 1
2 - 4
5 - 8
9 - 500
BOULDER
ADAMS
DENVER
JEFFERSON
ARAPAHOE
DOUGLAS
INSET

*Source: Denver Regional Council of Governments

TABLE 7

Means of transportation to place of work
in the Denver SMSA

TRANSIT MODE	WORKER RESPONSES	% OF TOTAL
Private auto (driver)	369,130	74.8
Private auto (passenger)	51,418	10.4
Bus, streetcar, or rail	20,675	4.2
Walked to work/and home	41,919	8.5
Other	10,424	2.1

Employment in the Denver CBD is primarily "white-collar" managers, executives, professionals and clerical workers from the governmental, finance, service and distributive type industries. The larger manufacturing complexes are away from the central area. "Blue collar" employment centers are dispersed through the Metropolitan area with medium and small-size firms within the central city. Many job openings in the blue collar and unskilled jobs are relatively near to transit dependent areas in actual miles, but are beyond normal commuting distances of the existing public transit services or are served by an indirect system of circuitous and time consuming transfers.

4. Other Socio-Economic Characteristics

a. Income and Economic Stability

In 1969 the median income within the Denver Central City was $9,654 and $10,777 for the metropolitan area as a whole. Households in the Denver SMSA with income over $15,000 included 25 percent of the total, while 6.8 percent of the SMSA families had income below the poverty level* in 1969. Of those families below the poverty level, 24.6 percent were receiving public assistance income.

The rural areas of the State of Colorado are less well off. The per capita adjusted gross income in 1970 was $3,129 in the Denver metropolitan communities, while it was $2,152 for the rest of the state. The Denver metropolitan region has shown a strong economic performance, especially during recent recessionary periods. While the National unemployment rate was at 6 percent, Denver was only 3 to 3.5 percent.

b. Population Age

The 1970 Denver SMSA population age distribution shows a large and growing proportion of the residents in the younger age groups. In the younger age category, 29.5 percent of the population is less than 15 years of age. At the opposite end of the age spectrum, 5.1 percent of the Denver population is more than 55, with 7.7 percent being older than 65 years.

c. Minority Group Population Trends

For the five county Denver Metropolitan region, 4.1 percent of the 1970 population base was Black and 11.3 percent had Spanish Surnames in 1970. The growth trend from 1960 to 1970 shows a 23 percent increase in the white population, 59 percent increase in persons of the Negro race, and 132.5 percent increase in persons with

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* The poverty threshold for a family of 4 was defined to be $3,743 in 1969.

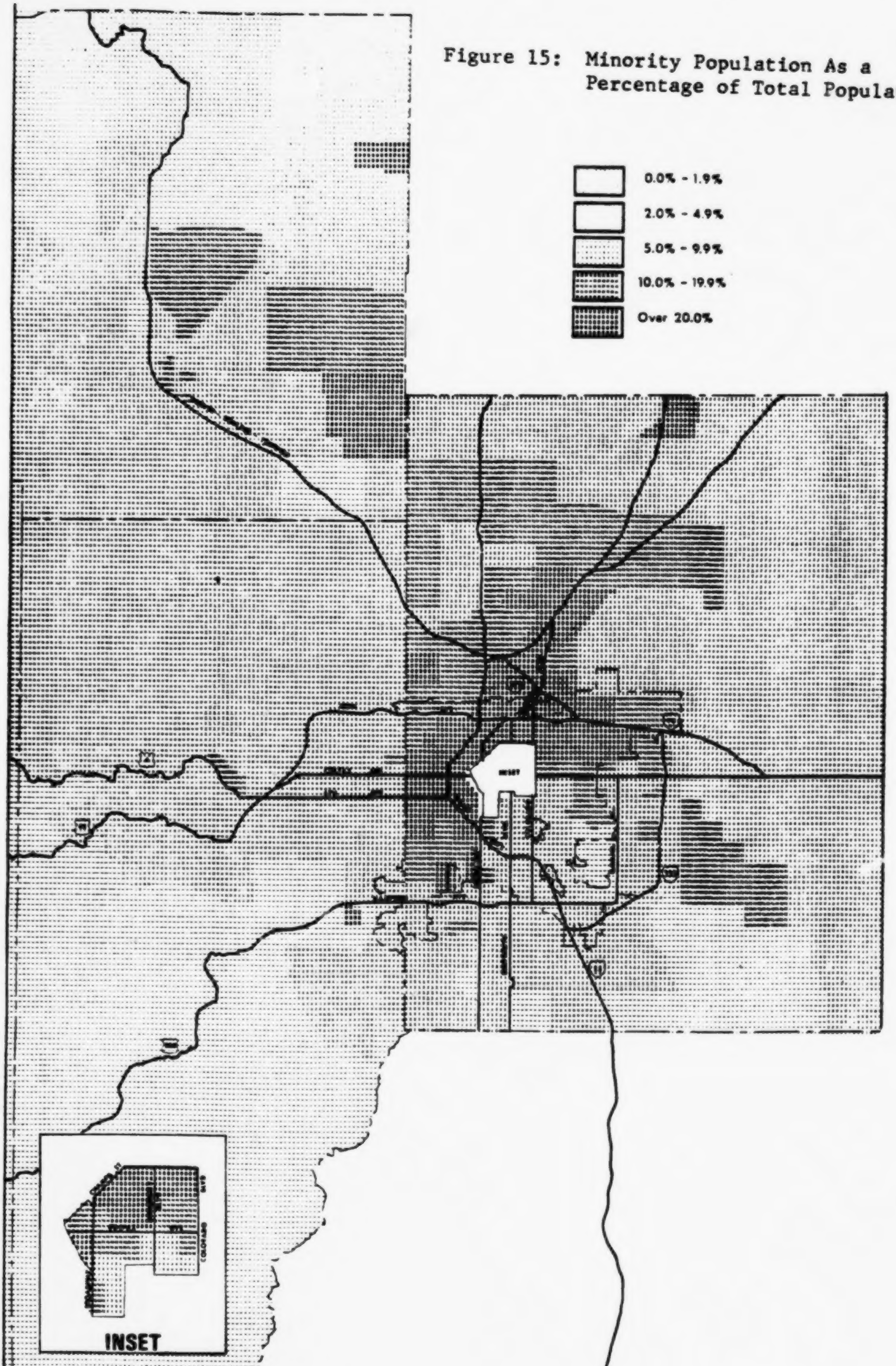
Spanish Surnames. Figure 15 illustrates the geographic distribution of minority groups in the metropolitan area, with highest densities occurring in the central city regions. Table 8 summarizes certain of the previously discussed demographic characteristics of the Denver SMSA population.

d. Political Structure

The Denver Metropolitan region is Colorado's major urbanized area. The Denver SMSA consists of more than 200 political entities, located in, and including, the counties of Adams, Arapahoe, Boulder, Denver, and Jefferson. Included are municipalities, school districts, sewage districts, water districts, park and recreation districts, fire districts, and other special purpose districts. Political power resides primarily in the Denver capital city, and the State legislature. The general concern for environmental issues in both public and private sectors has intensified in recent years in Colorado and Denver due to the region's abundant natural resources, open spaces, and quality deterioration of certain resources in areas of rapid unplanned growth. Legislation is currently pending concerning land use and natural resource planning.

In 1969 the Colorado General Assembly passed the Regional Transportation District Act to initiate comprehensive planning development, operation and maintenance of a public transportation system in the Denver Metropolitan Region. In 1971 the RTD entered into agreements with the Denver Region Council of Governments (DRCOG) and the Colorado Highway Division (CHD) to establish a Joint Regional

Figure 15: Minority Population As a Percentage of Total Population*


0.0% - 1.9%
2.0% - 4.9%
5.0% - 9.9%
10.0% - 19.9%
Over 20.0%
INSET

*Source: Denver Region Counci of Governments

TABLE 8

Demographic characteristics for the Denver Standard Metropolitan Statistical Area, 1970.

INCOME		
($) Family Income Class	Family Total	Percent of Total
< 3,743 (poverty)	20,572	6.8
< 4,999	43,172	14.2
5 - 14,999	185,713	61.0
<15,000	75,580	25.0
MEDIAN FAMILY INCOME = 10,777		

POPULATION AGE DISTRIBUTION		
Age Class	Number of Persons	Percent of Total
<15	362,195	29.5
<19	477,904	38.9
20-54	564,078	46.0
>55	185,547	15.1
>65	95,046	7.7

POPULATION WITH MINORITY GROUPS		
Group Category	Number of Persons	Percent of Total
White	1,021,447	84.6
Spanish Surname	138,928	11.3
Black	50,159	4.1
TOTAL	1,227,529	100.0

Planning Program (JRPP). These organization and regional planning agencies are important regional forces in the planning and development of transportation, land use and natural resource management in the Denver region.

e. Transit Dependent Population

The transit dependent population is generally composed of individuals from the following interrelated sectors: low income, minorities, elderly, young, and students. In the Denver region transit dependent groups include people too old or too young to drive cars or too poor to maintain an automobile or provide enough car service to meet all of the household's transit needs.

The greatest concentration of transit dependents in the Denver region is in a 28 square mile area including the Denver CBD, and the area to the north and the five points area, housing nearly 170,000 people. Travel via present public transit to employment on an average, 3.5 times longer than the same trip by car according to RTD studies. In addition, public transit provides minimal off-peak hour service.

III. STATEMENT OF ENVIRONMENTAL PROBLEMS

Public awareness and concern about environmental pollution problems have been intensifying over the past decade. Colorado is a state of abundant natural resources, beauty, and open spaces which have served as a basis for its leading economic activities of agriculture, tourism, and mineral industries; and these features have served to attract people to Colorado and particularly the Denver area. Environmental pollution problems result from such activities as the misallocation of resources within industrial plants, population growth and spatial concentration and modern transportation systems with absent planning and incentives to maintain resource quality levels.

Many aspects of urban growth land use and transportation activities influence environmental quality in the Denver Metropolitan area. In order to mitigate present environmental quality degradation and plan for more efficient management of natural resources in a growing region, it is necessary to analyze environmental conditions and problems in the Denver Metropolitan area. The following analysis of ambient air and water quality, noise, and solid waste in the Denver region provides a context for identifying the environmental impacts associated with alternative transportation emission control measures and aggregations thereof designed to attain and maintain local ambient air quality needs in the Denver area.

A. AMBIENT AIR QUALITY

1. Relevant Air Quality Standards

The Clean Air Act Amendments of 1970 directed EPA to set national air quality standards which would protect the public health and welfare from the known effects of the major air pollutants. In 1971 such air quality standards were established for six pollutants, including the four primarily associated with motor vehicles, namely carbon monoxide (CO), nitrogen dioxide (NO_2), photochemical oxidants (OX), and hydrocarbons (HC). Two sets of standards were established. The national primary ambient air quality standards defined levels of air quality which the Administrator judged to be necessary to protect the public health with an adequate margin of safety, and the national secondary ambient air quality standards defined levels which the Administrator judged necessary to protect the public welfare from any known or anticipated adverse effects of the pollutant. In the case of the four motor-vehicle-associated pollutants, the primary and secondary standards were identical.

In categorizing regions for purposes of developing implementation plans to ensure the achievement and maintenance of the air quality standards, the Denver AQCR was classified Priority I for carbon monoxide, photochemical oxidants, and hydrocarbons, and Priority III for nitrogen dioxide. A Priority III classification means that the levels of that pollutant were judged to be sufficiently low so that control measures need not be developed at the present time. In this Environmental Impact Statement, therefore, we are concerned only with strategies for the control of carbon monoxide, photochemical oxidants, and hydrocarbons. The primary standards for these three pollutants with brief summaries of the health effects associated with ambient levels greater than these standards are given below.

a. Carbon Monoxide

The national primary ambient air quality standard for carbon monoxide is 10 mg/m^3 (9 ppm) for a maximum 8-hour average and 40 mg/m^3 (35 ppm) for a maximum 1-hour average, not to be exceeded more than once per year. An important health property of carbon monoxide stems from its reversible reaction with hemoglobin to form carboxyhemoglobin. The carboxyhemoglobin level is determined by the carbon monoxide (CO) concentrations in the air, the duration of exposure and the level of physical and metabolic activity. An 8-hour CO concentration of 10 mg/m^3 will result in a 1.3 to 1.4 percent carboxyhemoglobin level and a 1-hour CO concentration of 40 mg/m^3 will result in a carboxyhemoglobin level of from 1.3 to 2.9 percent depending on the level of activity.

Recent studies indicate that a significant proportion of the population, those with coronary artery disease, are extremely susceptible to the effects of carbon monoxide. Increases in average carboxyhemoglobin levels from a background of 1.3 percent to a level of 2.9 percent have been shown to produce significant electrocardiographic changes and increased severity of angina pain for subjects engaged in very mild physical activity. A study in Los Angeles has generally confirmed these results by demonstrating that men with heart disease, exposed to levels of carbon monoxide found in freeway traffic, experienced decreased exercise tolerance and shortened time before the development of angina pain while exercising. In addition, exposure to carbon monoxide resulting in carboxyhemoglobin levels of 2 percent has been shown to have effects upon the ability to discriminate time intervals between auditory signals. Accordingly, the current standards afford a relatively small margin of safety for individuals with heart disease, some of whom are adversely affected at carboxyhemoglobin levels of 3 percent. Under these circumstances, the 8-hour standard provides a twofold margin of safety and the 1-hour standard provides about a 30 percent safety margin with moderate activity.

b. Photochemical Oxidants

The national primary standard for photochemical oxidants (primarily ozone) is 160 mg/m^3 (0.08 ppm) maximum 1-hour concentration not to be exceeded more than once a year. Adverse health effects resulting from oxidant exposures have been consistently observed in both experimental animals and man at exposures as low as 0.20-0.25 ppm, and significant effects have been found in animals at even lower concentrations. These effects include direct irritant action upon the lungs as well as effects upon other tissues in the body. In man oxidants are primary irritants which can aggravate asthma. In animals ozone has been shown to decrease defenses against infection and cause chromosomal changes in while blood cells.

In laboratory animals variations in age, activity, thyroid function, nutritional status, preexisting disease and temperature are known to significantly affect response to ozone, sometimes increasing sensitivity by two-to-threefold and more. Some of these factors (i.e., activity and preexisting disease) are already known to affect man's responses to oxidant (ozone) exposure.

Because of uncertainty regarding the nature of this dose-response relationship for exposure to low oxidant levels, as well as the many factors already recognized as influencing the response to oxidants in animals and man, the present standard is set sufficiently below the consistently observed effect level (0.20-0.25 ppm) to protect against the known effects. Further, the present standard is set to protect against moderate eye irritation. Though perhaps not a significant health problem, per se, eye irritation is still one of the most frequent air pollution complaints.

c. Hydrocarbons

The hydrocarbon standard is 160 mg/m^3 (0.24 ppm) for three hours, not to be exceeded more than once a year. The air quality standard for hydrocarbons is not based directly on health effects. The hydrocarbon standard is based upon the ability of hydrocarbons to contribute to the formation of photochemical oxidants for which there is a health related standard.

The hydrocarbon standard was established by quantifying the hydrocarbon-oxidant relationship for the purpose of obtaining a numerical hydrocarbon ambient air level consistent with the oxidant standard. The hydrocarbon-oxidant relationship used by EPA is based mainly on studies of aerometric data taken in a number of U.S. cities. Through examination of these data and other materials, a numerical value of 0.24 ppm hydrocarbon was derived for the hydrocarbon standard consistent with the oxidant standard. It should be noted, however, that the hydrocarbon level of 0.24 ppm is subject to some uncertainty due to our inability to accurately measure lower hydrocarbon concentrations, and to predict the impact of meteorologic factors upon chemical reactions involved in oxidant formation.

2. Monitoring Network

An assessment of the need for transportation controls to reduce motor-vehicle-associated pollutants begins with an evaluation of existing air quality. In principle, this assessment can be made directly by comparing air quality measurements with the ambient standards, or, in the event that suitable measurements have not been made within the area, by comparing urban diffusion model estimates with the standards. The use of a diffusion model requires appropriate emission and meteorological data as inputs. Estimates of the degree of control needed in the Denver AQCR are currently based on carbon monoxide and total oxidant observations made at the Federal CAMP station located in the middle of a traffic island near the downtown Denver central business district. At the present time, the station is operated by state personnel. Carbon monoxide observations are made by the approved non-dispersive infrared method, and total oxidants are measured by the potassium iodide colormetric method. Both pollutants are measured continuously. Carbon monoxide data from three new monitoring stations established in the City of Denver in 1973 are now becoming available. The location of these stations and of the CAMP station are shown in Figure 15. The National Jewish Hospital is located at the intersection of two main arterials in East Denver. The Children's Hospital is located in a typical Denver residential area, and the Overland station is located in the southern end of the Platte River Valley, near two major arterials in a residential district.

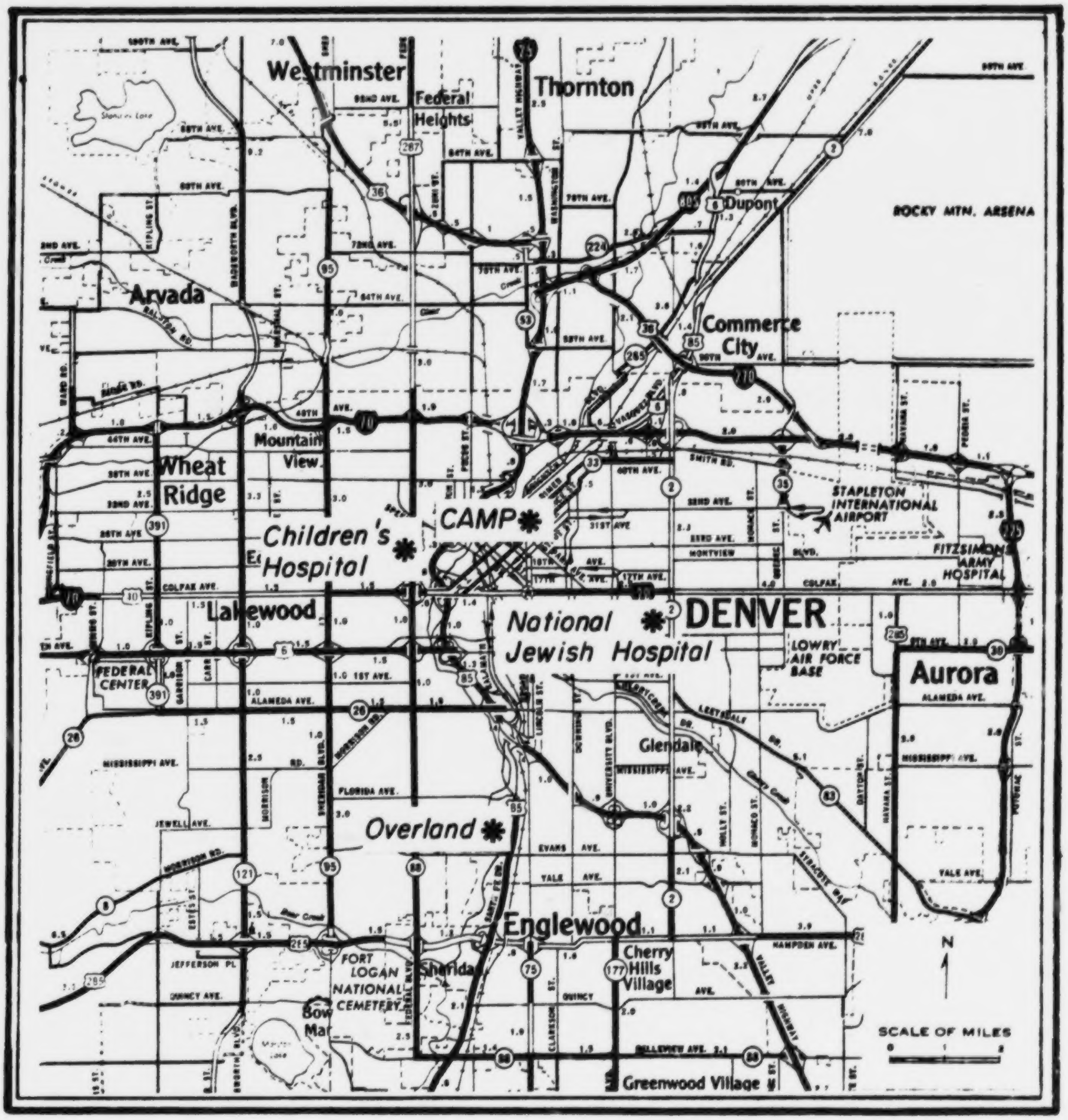

Westminster
Thornton
Federal Heights
Dupont
ROCKY MTN. ARSENA
Arvada
Commerce City
Wheat Ridge
Mountain View
CAMP
Children's Hospital
STAPLETON INTERNATIONAL AIRPORT
FITZSIMONS ARMY HOSPITAL
Lakewood
National Jewish Hospital
DENVER
LOWRY AIR FORCE BASE
Aurora
FEDERAL CENTER
Glendale
Overland
Englewood
Cherry Hills Village
FORT LOGAN NATIONAL CEMETERY
Sheridan
Bow Mar
Greenwood Village
SCALE OF MILES
N

Figure 15. Map showing locations of monitoring stations in downtown Denver

3. Methodology for Estimating Future Air Quality

The basic concept used in projecting pollutant concentration levels was the proportional model. This model assumes simply that within an urban area the concentration of a primary pollutant (i.e., one that is emitted directly into the atmosphere, such as carbon monoxide and hydrocarbons) is linearly related to the quantity of the pollutant that is emitted within that area. The initial relationship between air quality and emission rate is established from concentration measurements made over a 1-year period and emission estimates made for this same reference period. Emissions within the urban area are projected into the future by considering such factors as the expected growth rates of existing sources, the introduction of new sources, and the effect of regulatory controls on old sources. The predicted ambient concentration is then obtained by the proportional model.

To determine the need for transportation controls, this basic procedure was employed to project the pollutant concentration levels that could be expected in 1975 and 1977 without the application of transportation controls. Comparison of these potential air quality levels with the appropriate standards gave the allowable emission levels, which in turn formed the basis for the development of the required emission controls.

A vehicle emission estimate is the product of two factors; vehicle miles traveled (VMT) and an emission factor or rate. Standard techniques were employed for the determination of VMT, speeds, and vehicle age distributions. Details are given in the TRW report entitled

Transportation Control Strategy Development for the Denver Metropolitan Area. Estimates of VMT were based principally on summaries, prepared by the Colorado Department of Highways, of the total vehicle miles of travel per day in the Denver region in 1969 and of projected 1990 values. In addition, in 1971 another comprehensive volume count program was undertaken. Data from this program served as the basis for updating VMT in the 12-square-mile Central Area used in the projection of carbon monoxide emissions. On the basis of these data, plus additional traffic data obtained in 1965, it was determined that the growth rate from 1969 to 1971 had been approximately 3 percent per year compounded for the City of Denver, 5 percent per year for Arapaho and Adams Counties, and approximately 6 percent per year for Jefferson County. For the 12-square-mile Central Area, historical volume count data indicated that vehicular travel was growing at a rate of approximately 1.5 percent per year compounded in the lower part of the Central Area, which included the central business district, to approximately 3 percent per year compounded in the northern part of the area.

The vehicle emission factors used in this study are based on measured and projected emission rates for each vehicle class considering age of vehicle, effectiveness of emission controls, average speed, and vehicle age distribution. The impact of Federal new car standards is considered in both the present and projected vehicles.

The equation for calculating emission factors is shown below:

$$e_{np} = \sum_{i=n-12}^{n+1} c_i \cdot d_i \cdot m_i \cdot s_i$$

e_{np} = emission factor in grams per vehicle mile for calendar year n and pollutant p,

c_i = the 1975 Federal test procedure emission rate (grams/mile) for pollutant p for the i^{th} model year, at low mileage

d_i = the controlled vehicle pollutant p emission deterioration factor for the i^{th} model year at calendar year n,

m_i = the weighted annual travel of the i^{th} model year during calendar year n (the determination of this variable involves the use of the vehicle model year distribution),

s_i = the weighted speed adjustment factor for the i^{th} model year vehicles.

c_i is based on a recent study of light-duty vehicle exhaust emission rates in Denver. d_i, the deterioration factor, accounts for the aging or deterioration of emission control devices. m_i, the weighted annual mileage is determined as follows:

$$m_i = \frac{V_i \times D_i}{\Sigma V \times D}$$

V_i = fraction of each model year vehicle in use on December 31 of year,

D_i = average miles driven of each model year vehicle.

s_i, the speed adjustment factor, varies roughly inversely with average route speed. A more complete discussion of the calculation procedure is given by Kircher and Armstrong.

a. Carbon Monoxide

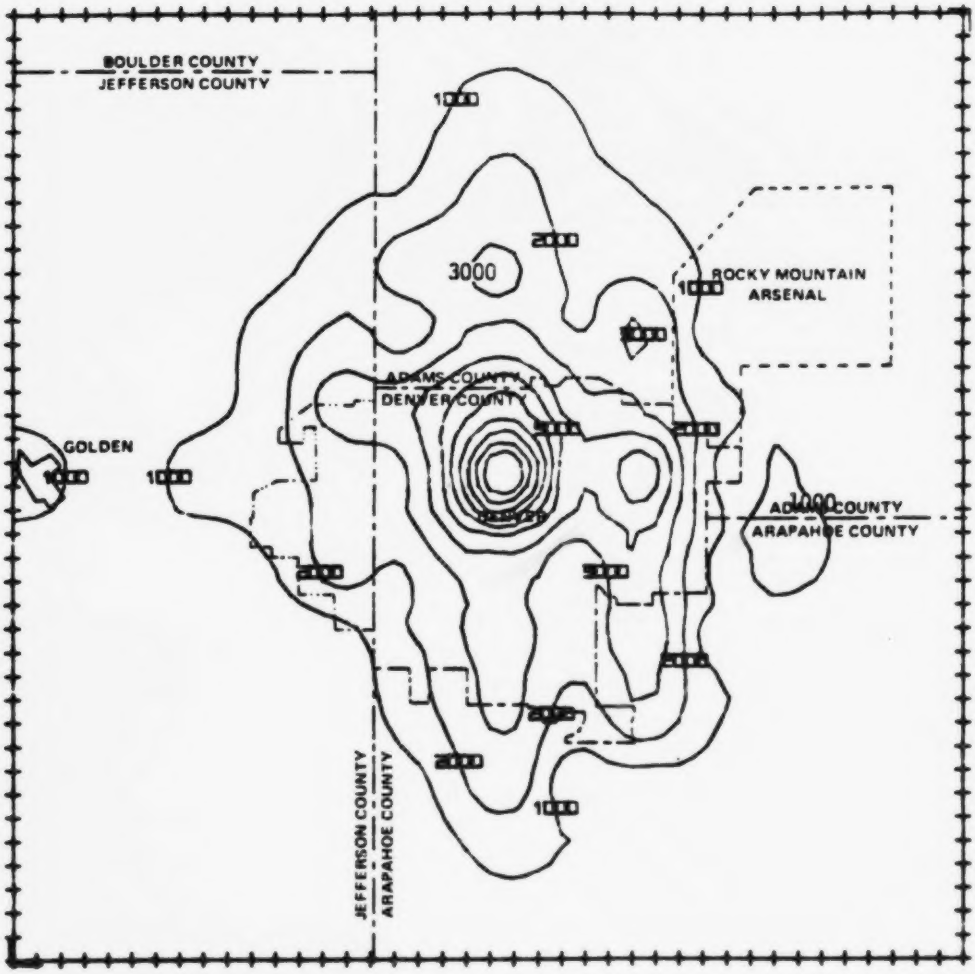
Recent estimates of the relative contributions of emission sources in our urban areas show the following mix among three source categories:

Source	Percentage of Total Emissions
Automobiles	77-87
Trucks, buses, and motorcycles	8-10
Stationary sources	3-15

Within the central business district of an urban area, the relative contribution of stationary sources is even less. For the Denver Central Area the contribution of non-vehicular sources to carbon monoxide emissions is estimated to be less than 1 percent (see the State of Colorado Air Pollution Control Transportation and Land Use Plan, pp. 3-6). It is thus apparent that a significant decrease in the ambient carbon monoxide concentration levels in the downtown areas of the Denver AQCR can be achieved only by reducing vehicular emissions.

Field measurements and urban diffusion models show that the ambient concentration of carbon monoxide decreases rapidly with distance from typical sources such as traffic intersections, highways, and business districts. Figure 16, taken from the TRW report, is an example of carbon monoxide concentration isopleths in the Denver area calculated by means of a diffusion model. The purpose of this figures is to illustrate the relative concentration of carbon monoxide within the area on a typical day, rather than absolute concentrations at particular locations.

The Denver VMT data, when distributed throughout the area according to a 1-square-mile-mesh grid network, showed that the greatest volume of traffic -- and hence the highest emissions of carbon monoxide -- occurred in the Central Area. Projections of ambient carbon


BOULDER COUNTY
JEFFERSON COUNTY
1000
2000
3000
ROCKY MOUNTAIN ARSENAL
1000
2000
ADAMS COUNTY
DENVER COUNTY
3000
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GOLDEN
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1000
DENVER
1000
ADAMS COUNTY
ARAPAHOE COUNTY
2000
3000
2000
2000
2000
1000
JEFFERSON COUNTY
ARAPAHOE COUNTY

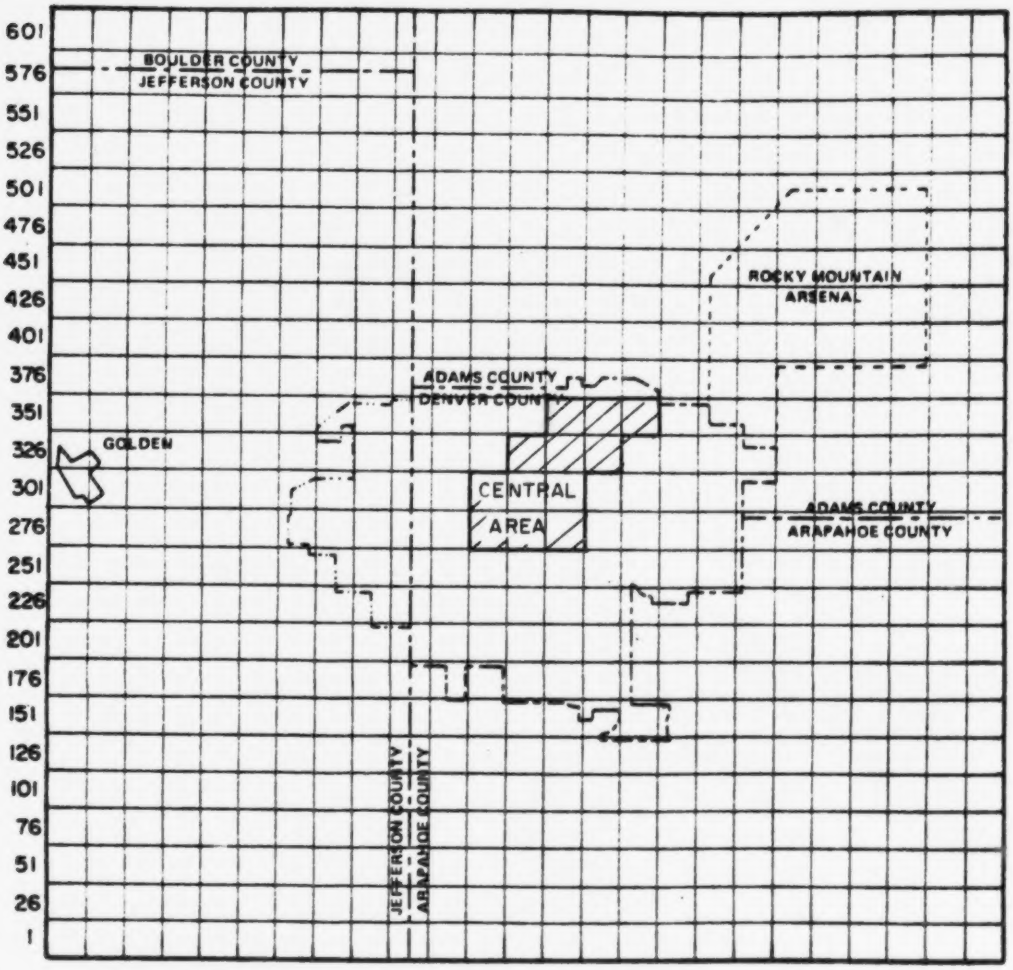
Figure 16. Sample carbon monoxide isopleths showing relative concentration in the Denver area on a typical day.

monoxide concentrations have therefore been based on emissions within the Central Area and concentration measurements at the CAMP station, also within the Central Area. This 12-square-mile area, shown in Figure 17, lies to the south of 52nd Avenue, 1/2 mile north of FA1 70 and to the east of FA1 25 as far as Colorado Boulevard.

b. Special Procedures for Hydrocarbons/Photochemical Oxidants

As mentioned previously, the importance of hydrocarbons as pollutants lies not in any adverse effects produced by ambient concentrations of the hydrocarbons themselves, but rather in the role played by them in the formation of photochemical oxidants. The photochemical oxidants of concern are secondary pollutants formed by the complex reactions of sunlight acting upon hydrocarbons and nitrogen oxides. Because of the lag between the time of emission of the precursor pollutants and the formation of the photochemical oxidants, maximum oxidant concentrations frequently occurs in areas far removed from principal sources of the precursor pollutants. Further complicating the calculation of any required reduction in hydrocarbon emissions is the fact that the photochemical reactions involved are inherently non-linear. Thus, reducing the concentrations of the precursor pollutants by one-half cannot necessarily be expected to result in a corresponding reduction in the concentration of photochemical oxidants.

The procedure set up by EPA to determine the emission reduction for hydrocarbons required to achieve the photochemical oxidant air quality standards is based on a relationship between peak 6 a.m. to 9 a.m. hydrocarbon emissions and maximum oxidant formation determined


601
576
551
526
501
476
451
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401
376
351
326
301
276
251
226
201
176
151
126
101
76
51
26
1
BOULDER COUNTY
JEFFERSON COUNTY
ROCKY MOUNTAIN ARSENAL
ADAMS COUNTY
DENVER COUNTY
GOLDEN
CENTRAL AREA
ADAMS COUNTY
ARAPAHOE COUNTY
JEFFERSON COUNTY
ARAPAHOE COUNTY

Figure 17. Denver grid showing location of Central Area. Small squares are 1-mile on each side.

from data from a number of cities. The relationship, expressed as a curve, is shown in Figure 18, taken from Appendix J of the Federal Register (August 14, 1971). It is assumed that the reduction given by this curve will also be adequate for the attainment of the hydrocarbon standard.

Because of the manner in which oxidants are formed and dispersed over the entire metropolitan area, the hydrocarbon emissions have been aggregated over an area comprised of all of Denver county and the part of Adams County shown in Figure 17.

In contrast to carbon monoxide, considerable amounts of hydrocarbons are emitted into the urban atmosphere from non-vehicular sources. Estimates of the relative contributions from three source categories, compiled from a number of urban areas, are shown below:

Source	Percentage of Total Emissions
Automobiles	50-65
Trucks, buses, and motorcycles	5-10
Stationary sources	25-45

For the area used in the hydrocarbon emission calculations, the contribution from aircraft and stationary sources is estimated in the Colorado State Plan to be 32 percent. Thus, strategies directed toward the curtailment of stationary source emissions can be an effective part of any plan for the reduction of hydrocarbons in the Denver AQCR.

4. Baseline Air Quality Data

Emission rates and air quality were projected from 1971 data. As mentioned previously, the CAMP station provided the baseline

APPENDIX J

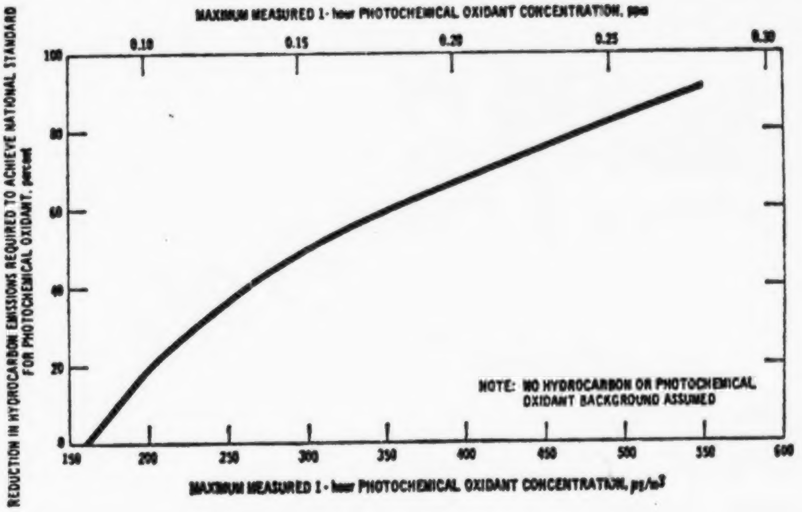


Figure 1. Required hydrocarbon emission control as a function of photochemical oxidant concentration. (Reference: Air Quality Criteria for Nitrogen Oxides, AP-84, Environmental Protection Agency, Washington, D.C., January 1971.)

Figure 18. Appendix J, Federal Register, August 14, 1971.

carbon monoxide and oxidant data, and was located in the Central Area at a site believed to be representative of zones subject to maximum vehicular emissions. Recent observations at the new Denver sites have so far comfirmed the suitability of the CAMP data for use in projections of carbon monoxide. On the other hand, because of their method of formation and the part played by non-vehicular sources, it is not obvious that the maximum concentrations of photochemical oxidants will occur near the CAMP site. However, the oxidant data from this site provided the only available 1971 data for use in the air quality projections. It is quite possible that the CAMP station is well located to measure maximum oxidant concentrations, since the mid-day return flow of air discussed in Section II-A-3 may bring air back to the downtown area after the peak morning vehicular emissions introduced from downtown traffic have undergone maximum conversion to photochemical oxidants.

The air quality regulations allow the standards to be exceeded once a year. Accordingly, the second highest 1-hour and 8-hour average concentrations observed during the reference year were used for the rollback calculations.

a. Carbon Monoxide Data and Required Reduction

The second highest 1-hour and 8-hour average carbon monoxide concentrations recorded at the CAMP station in 1971 were 51 ppm and 24.7 ppm, respectively. The rollback calculations follow:

1-Hour Period

$$\frac{A - C}{A - B} \times 100 = \text{Percent reduction required}$$

where A = Existing air quality (51 ppm)

B = Background concentration (0 ppm)

C = National standard (35 ppm)

Thus $\frac{51 - 35}{51 - 0} \times 100 = 31.4$ percent

8-Hour Period

$$\frac{A - C}{A - B} \times 100 = \text{Percent reduction required}$$

where A = 24.7 ppm

B = 0 ppm

C = 9 ppm

Thus $\frac{24.7 - 9}{24.7} \times 100 = 63.6$ percent

b. Oxidant Data and Required Reduction in Hydrocarbons

The second highest 1-hour average oxidant concentration recorded at the CAMP station in 1971 was 0.18 ppm. Appendix J of the August 14, 1971 Federal Register gives the reduction in hydrocarbon emissions required to achieve the national standards as 60 percent.

5. Projected Air Quality

Using the procedures outlined above, vehicular emissions of carbon monoxide and hydrocarbons were calculated for the years 1971 to 1986. These vehicular emissions were then added to non-vehicular emissions (i.e., emissions from stationary sources in the case of carbon monoxide, and from aircraft and stationary sources in the case of hydrocarbons) and the total emissions used to project ambient carbon monoxide and oxidant levels from the 1971 observed values. The non-vehicular emissions used were taken from the Colorado State Plan (pp. 6-41 and 6-42) and were the amounts estimated to take place in the absense of transportation control measures. For carbon monoxide and hydrocarbons, the estimates were 208 and 13,847 tons per year, respectively, for the areas in question. In the plan, emissions from this source category were held constant from 1971 through 1982; in the present calculations these values were used through 1986. Vehicular calculations are based on the successful operation of the Federal Motor Vehicle Control Program (FMVCP) to control emissions from new motor vehicles. The projected vehicular emissions are estimated by vehicle class and model year grouping so that the relative effectiveness of alternative strategies involving the selective use of retrofit devices or engine modivications can more easily be evaluated. The principal vehicle classes are: (1) light-duty (gasoline powered vehicles rated at 6000 pounds gross vehicle weight or less), (2) heavy-duty (gasoline powered vehicles rated at more than 6000 pounds), and (3) diesel-powered vehicles. Light-duty vehicles are broken down into:

(1) pre-1968 model years (pre-controlled),

(2) 1968-1974 model years,

(3) 1975 model year - emissions from 1975 vehicles are based on the interim standards prescribed by EPA on April 11, 1973, and

(4) post-1975 model years.

The results, which are presented graphicallal below, do not include the possible impact of major changes in the public transportation system, or of any control strategies other than the FMVCP. In interpreting these curves, it should be remembered that the air quality projections are based on the second-highest concentration observed in a single year, and that since the severity and frequency of meteorological conditions causing high pollution levels differ from year to year, considerable scatter about the projected curves must be expected.

a. Carbon Monoxide Projections

Figure 19 gives the total emissions of carbon monoxide in the Central Area per day through December 1986, and the breakdown by emission category. The scale at the right of the figure converts emissions to the maximum 8-hour average concentration expected in a 1-year period. Figure 19 shows that the 8-hour carbon monoxide standard -- which is the most restrictive of the two standards -- will not be achieved until 1982 unless additional control measures are undertaken. It also shows that the major contribution during the critical 1975-1977 period comes from 1968-1974 light-duty vehicles, but that a substantial contribution in 1975 also comes from pre-controlled vehicles. Heavy-duty vehicles are not covered by the Federal Motor Vehicle Control Program, and by 1986 emissions from this class of vehicle make up approximately one-half of the total emissions.

b. Hydrocarbons/Oxidant Projections

Figure 20 gives the total emissions of hydrocarbons in the selected area (Denver County and a part of Adams County) per day through December 1986, and the breakdown by emission category. The scale at the right of the figure which converts hydrocarbon emissions

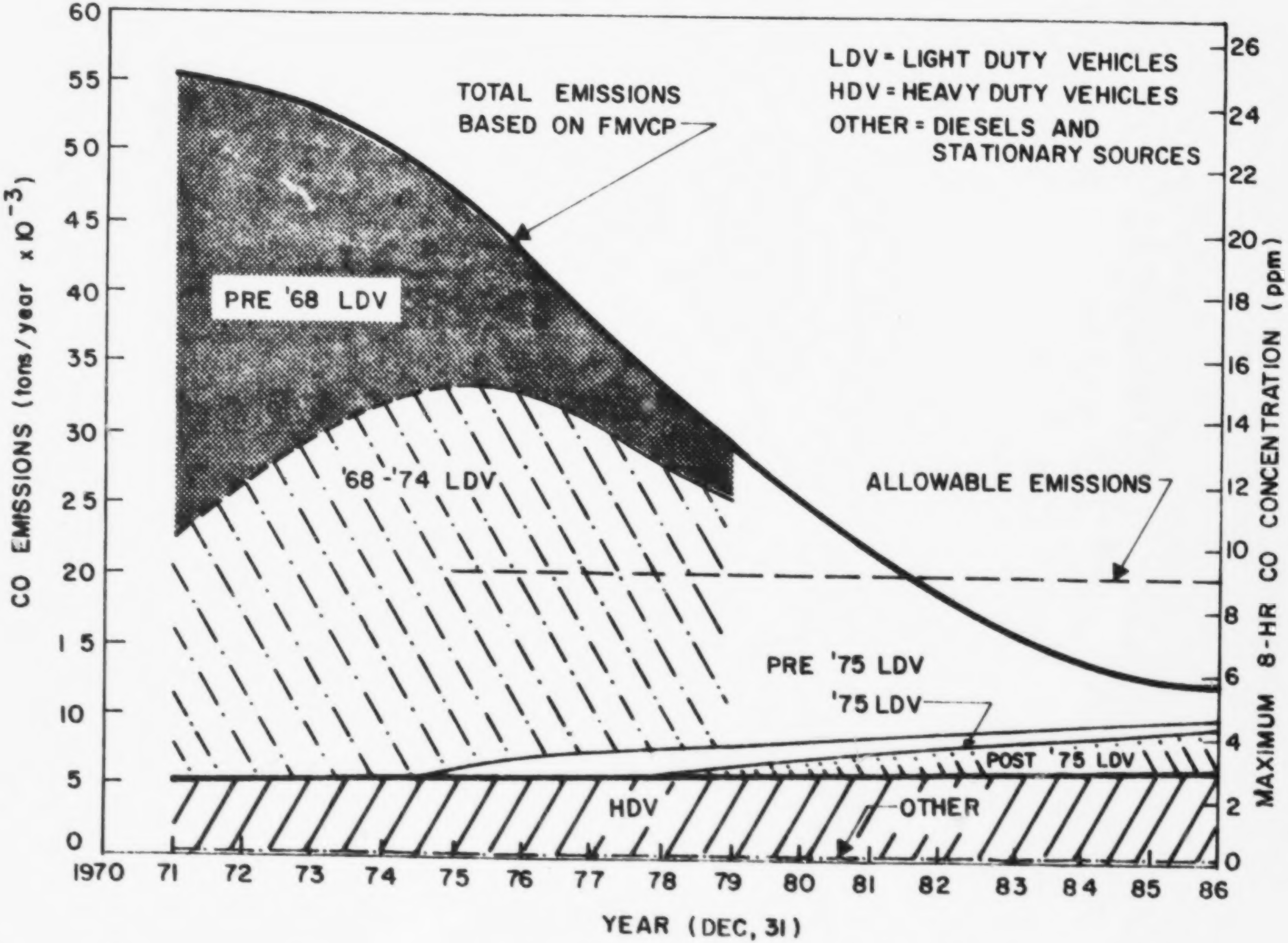


Figure 19. CO emissions in Central Area of Denver by vehicle class and model year groupings, for "no transportation plan" condition.

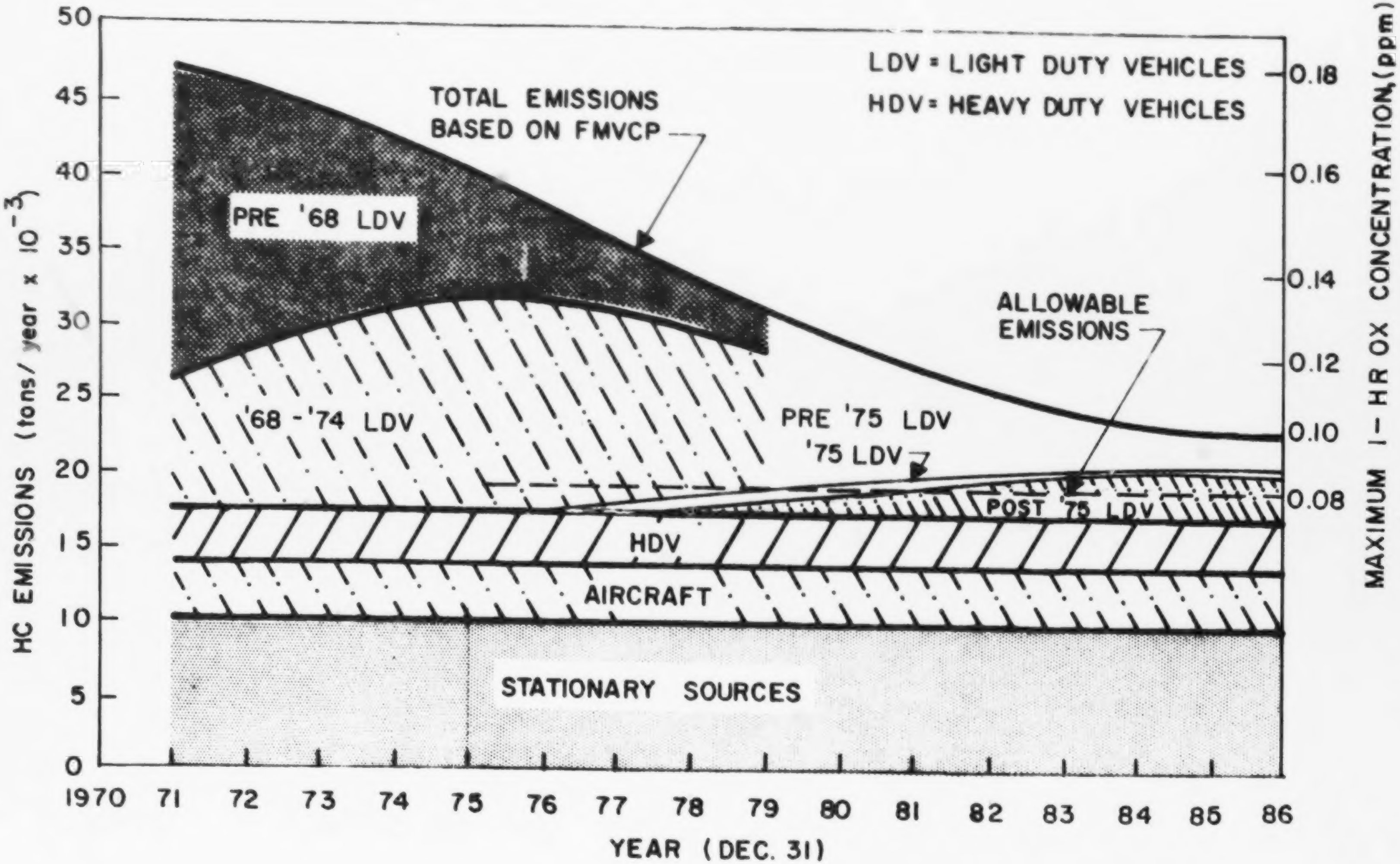


Figure 20. HC emissions in selected area by vehicle class and model year groupings, for "no transportation plan" condition.

the maximum 1-hour concentration of photochemical oxidants in a 1-year period was obtained by means of Appendix J (Federal Register, August 14, 1971). The contributions of the various vehicle classes as a function of time are similar to those for carbon monoxide. The principal difference between Figures 19 and 20 are in the relative contributions of motor vehicles and of aircraft and stationary sources. Because of the major contributions of these latter two sources, the allowable emission level is not reached by 1986. In fact, it is unlikely that this level can be achieved without the use of control measures on non-vehicular sources, since vehicular emissions are projected to reach a minimum about this time as a result of the replacement of pre-1975 cars. After the mid-1980's vehicular emissions typically are projected to increase with time as a result of continued growth in vehicular traffic.

B. AMBIENT WATER QUALITY

Water resources in Colorado originate primarily within the state, but are very important regionally, since 18 states share in the use of its waters. Water pollution occurs primarily because ingredients are added from water-course interfaces and water users returning water to the system. Annual virgin stream flow in the South Platte Basin, in which the Denver Metropolitan Area lies, is about 2.2 million acre feet, of which Colorado is legally entitled to 2.1 million acre feet. Colorado is restricted by interstate compacts to 34.7 percent of the 11 million acre feet produced by the Colorado River System, thereby increasing the quantity and quality characteristics of the South Platte System.

The quality of surface waters in the South Platte River Basin ranges considerably from the pristine condition of many creeks to the sewage polluted section of the South Platte River in the immediate Denver area. The quality of the main stem of the South Platte River decreases as it approaches Denver and recovers somewhat after leaving the metropolitan area. Sewage treatment plant effluent is the major cause of water quality degradation in the South Platte River with surface runoff becoming significant as urbanization increases. Irrigation return flows, feedlot runoff, and acid mine drainage are also factors detrimental to the quality of waters in the South Platte River Basin. Most industries in the Denver area are linked with the Denver Metropolitan sewage plant and thus do not discharge directly to the water system of the basin. However, the South Platte River is used as a source of cooling water.

The quality of ground water is considered to be good in most areas of the basin. However, mine drainage, deep well injection, septic tanks, irrigation, and the deteriorated quality of surface waters interacting with ground water has impaired ground water quality in a few locations. Ground water in the vicinity of Brighton contains concentrations of nitrates, chlorides, and alkyl-benzene-sulfonate in excess of limits set by the United States Public Health Service for public water supplies.

In general, the South Platte is the most polluted stream in the state, primarily because the major portion of Colorado's population, industry, and agricultural feedlots are located in this area of the state. Various users and user categories compete for the South Platte's water quality levels supportive of the large and rapidly growing population base in the Denver SMSA.

Various activities present actual or potential threats to watersheds in Colorado affecting the South Platte Basin. Recreation development in Summit County is affecting the Blue River and Snake River drainages, which influence the Denver water supply. Interstate highway construction from Gypsum to west of Vail in Eagle County is affecting the Eagle River drainage. Improperly managed activities such as these can cause rapid water runoff, soil erosion, stream silting, and drainage to vegetation in the region. Another problem area is the encroachment of human activity on natural flood plains affecting the ecology and generating pressure for flood control measures. Cherry Creek Dam in the Denver region, and Chatfield Dam on the South Platte, now under construction, are public management measures to prevent environmental impacts.

Finally, as water use becomes more intense, being recycled more as it travels downstream, the problem of salt occurs. Repeated use increases salt content, and excessive salt renders water useless for agriculture and land irrigation. The Arkansas and Colorado Rivers are experiencing salt levels causing serious concern, and the importance of the South Platte River system to the Denver SMSA highlights the importance of land use and water resource management to maintain resource quality to meet increasing human needs.

C. NOISE

Noise analysis, impact assessment and environmental control are relatively new areas of community concern in contemporary society. Before reviewing the noise environmental conditions in the Denver Metropolitan region, a generic over view of noise generation in the environment, particularly from transportation related sources, is presented, followed by a specific assessment of noise conditions in Denver.

1. Noise in the Community Environment

The impact of noise pollution in contemporary communities has become a major concern to many persons. Of the various noises present, those related to transportation systems are considered to be the principal source of annoyance. Approximately 55 percent of the total noise within a typical community is produced by motor vehicles, and approximately 15 percent is produced by aircraft. The third major source of community noise is the human voice, producing approximately 12 percent of ambient levels.

The principal factors affecting vehicular noises may be divided into two groups -- those related directly to the type of vehicle and its operating characteristics, and those associated with traffic conditions and characteristics of the roadway and surrounding topography.

a. Vehicle Types and Operating Conditions

For purposes of this discussion, vehicles have been grouped into four categories: automobiles, trucks, buses, and rail. Some noise level characteristics of each category are summarized below.

Automobiles: The noise level 100 feet from a car operating at highway speeds (approximately 55 to 65 mph) usually falls between 65 and 75 dbA. However, noise levels of 85 dbA are reached with the use of snow tires. Because of the deterioration of the exhaust silencer system, noise levels from passenger automobiles greater than two years of age average about 2 to 3 dbA higher than noise levels from new cars.

Trucks: Heavy-duty highway trucks are the source of the highest highway noise levels. Typically, noise from such vehicles is approximately 10 dbA louder than from a passenger automobile . Sources of noise on trucks, and highway vehicles in general, are the tires, engine, exhaust system, transmission and air flow. Also, the level of noise increases with truck age. The noise level from a diesel truck exceeds that of a gasoline-powered truck by about 10 dbA.

The amount of noise generated by tire-roadway interaction is a function of the type of tire. In general, the noise level is not highly sensitive to the rib pattern, but certain retreads are extremely noisy. Heavy-duty crossbar tread (typical of automobile snow tires) produces moderate levels of noise.

The noise characteristics of utility and maintenance vehicles are similar to those of trucks.

Buses: Highway noise generated by buses is caused primarily by tire-roadway interaction. At highway speeds, noise levels ranging from 80 to 87 dbA are not uncommon. In addition, the air intake grille frequently creates an impulse in excess of 90 dbA as a bus accelerates from a stop.

Rail: The power plant of the diesel-electric locomotive is the primary source of railroad noise. The level of noise from railroad and rapid transit systems also depend upon factors such as wheel-track interaction, wearing of wheels and track, design of railbed, and the rail joints. A condition that primarily affects subway systems is that noises reverberate in tunnels and underground stations, thus annoying passengers and workmen.

b. Traffic Conditions and Roadway Characteristics

Traffic conditions are dependent largely upon average daily traffic (ADT) volumes, the operating speed of the vehicles, and the truck traffic. ADT volumes are considered to operate at level of service "C" (as defined in the Federal Highway Administration's Highway Capacity Manual). This condition represents a combination of speeds and volumes that create maximum noise.

On level ground, an observer 100 feet from traffic moving at 60 mph would record 66 dbA and 71 dbA at flows of 2,000 and 6,000 vehicles per hour, respectively. Increasing the operating speed of automobiles generally increases the noise level; in contrast, the noise level of trucks is nearly independent of operating speed. For example, observations 100 feet from a roadway yield:

Single car at	20 mph	50 dbA
	40 mph	58 dbA
	60 mph	64 dbA
Single truck at	25 mph	76 dbA
	50 mph	76 dbA

These data also show the relative contribution of a single car and a truck to highway noise. Because of the difference between the two, the proportion of truck traffic to total highway users is a significant index of highway noise.

Roadway characteristics include configuration, pavement type, and grade. Roadway configuration, or geometric design and alignment, influences audio impacts because capacity and speeds are governed by the source. Pavement type and tire interaction is a critical source of noise pollution, especially with heavy-duty vehicles. The relative smoothness of pavement can increase or reduce noise levels by 5 decibels. The steepness of grades is another factor that effects roadway noise. Trucks are more significantly affected than automobiles. Grades of 2 percent or less result in negligible noise level increases. Expected increases with respect to grades are 2 dbA for a 3 to 4 percent grade, 3 dbA for a 5 to 6 percent grade, and 5 dbA for grades greater than 7 percent.

The attenuation of sound with distance is affected by the design of the roadway. As an example, typical noise levels for three highway configurations with a volume of 6,000 vehicles per hour, traveling at 60 mph, are:

	Noise Level (dbA)	
Configuration	At 100 ft	At 500 ft
Depressed 20 feet	58	47
At grade	71	62
Elevated 20 feet	60	59

The dominant factors affecting noise generation at different speed classes are:

High speed - tire-roadway interaction

Low speed - exhaust system and transmission

2. Noise in the Denver Region

In 1972, the Mayor of the City of Denver commissioned a Noise Control Study Committee to evaluate noise conditions in the Denver region and make recommendations concerning the need for enactment of a noise control ordinance. The surveys conducted by this committee provide background and vehicular noise levels for the Denver area. It should be noted that the consensus opinion of the Mayor's Noise Control Study Committee, as reported May 1973, was that the City and County of Denver enact a noise control ordinance.

The information provided in Table 9 presents a compilation of background and point source measurements from the Study Committee surveys. The background levels in the table summarize ambient noise readings made in three land-use zones (residential, commercial, and industrial) in the absence of nearby traffic and obvious individual sources. The total observed levels are compiled from all measured sources, including traffic, for the three zones plus 21 readings from special source, regardless of location. Based on this study, noise levels in a residential area will average about 45 to 48 decibels, while average readings in commercial and industrial zones will range from about 55 to 61 decibals and from about 64 to 70 decibels, respectively. Extreme values for each category are also given in the table.

TABLE 9

LEVELS OF NOISE BY ZONE IN THE CITY OF DENVER

Background Levels			
Zone	Number of Readings	Range High/Low (dbA)	Average Noise Level (dbA)
Random	---	---	---
Residential	35	53/35	45
Commercial	5	61/47	55
Industrial	6	75/58	64

Total Observed Levels			
Zone	Number of Readings	Range High/Low (dbA)	Average Noise Level (dbA)
Random	21	107/50	74
Residential	42	91/35	48
Commercial	22	85/47	61
Industrial	33	99/57	70

Vehicular noise levels measured within the Denver area are summarized by class of vehicle and speed in Table 10. These data are presented graphically in Figure 21, and show the expected pronounced increase in noise level with increasing speed for light-duty vehicles, and little increase in noise level with increasing speed for trucks and buses once the initial shifting of gears has been completed. The data also show a marked increase in noise level in going from light-duty vehicles to buses to trucks, as expected.

Table 11 compares measured noise levels for vehicles by class with the maximum permissible levels recommended by EPA, Region VIII. Based on these limited data, the average noise level from motor vehicles in the Denver area approximates the maximum permissible levels.

D. SOLID WASTE

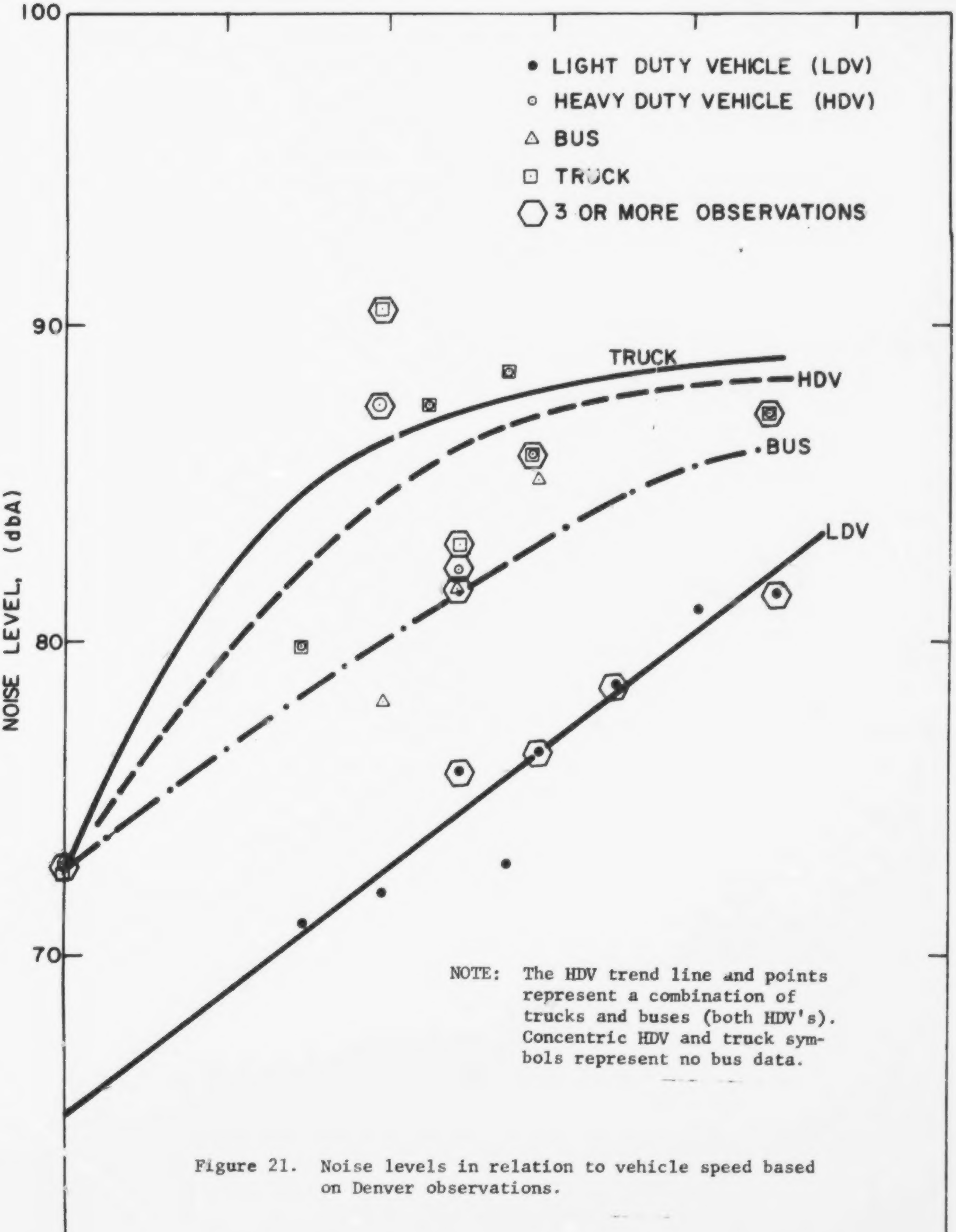
Nationwide, according to the Council on Environmental Quality, regulation of solid waste management practices, other than for public health protection, is in a rudimentary state. However, statewide and regional solid waste planning is on the rise. This is leading to increased regulatory activity such as regulations against open dumps and controls over landfill practices.

The solid waste collection and disposal system in the Denver Metropolitan Area is representative of a traditional system in that most solid wastes are temporarily stored at their generation point, collected by public and private agencies, and disposed of in sanitary landfills. A small percentage of the solid wastes are recycled; e.g., glass, paper and cans, and scavenger operations recover some materials such as junk cars.

TABLE 10

AVERAGE NOISE LEVELS - DENVER, COLORADO

Speed (mph)	Light-Duty Vehicle (<8000 lb)		Heavy-Duty Vehicle (>8000 lb)					
			Total HDV's		Bus		Truck	
	Number of Sources	Noise (dbA)	Number of Sources	Noise (dbA)	Number of Sources	Noise (dbA)	Number of Sources	Noise (dbA)
Idling	1	64	8	73	4	73	4	73
15	1	71	1	80	--	--	1	80
20	2	72	4	88	1	78	3	91
23	--	--	2	88	--	--	2	88
25	9	76	11	82	6	82	5	83
28	1	73	2	88	--	--	2	89
30	47	76	14	86	1	85	13	86
33	2	82	--	--	--	--	--	--
35	8	78	--	--	--	--	--	--
40	2	81	--	--	--	--	--	--
45	10	82	52	87	--	--	52	87



NOTE: The HDV trend line and points represent a combination of trucks and buses (both HDV's). Concentric HDV and truck symbols represent no bus data.

Figure 21. Noise levels in relation to vehicle speed based on Denver observations.

TABLE 11

NOISE LEVELS BY VEHICLE CLASS

Vehicle Class	Vehicle Speeds[a]					
	Less Than 35 mph			Greater Than 35 mph		
	Measured Levels (dbA)[b]	Maximum Levels[c]		Measured Levels (dbA)[b]	Maximum Levels[c]	
		Before 1/1/75	After 1/1/75		Before 1/1/75	After 1/1/75
HDV[d]	73-88	84/90	80/86	87	86/92	82/88
Bus	73-82	---	---	None Available	---	---
Truck	73-91	---	---	87	---	---
LDV[d]	64-82	74/80	74/80	78/82	80/86	80/86

[a] Speeds represent observed speeds for measured levels and posted speed limits for EPA values

[b] This represents the range of average values as determined from Table 10. All measurements were taken 25 feet from source.

[c] These are the maximum permissible levels recommended by the EPA (Region VIII). Values given are for representative distances from source (50 ft/25 ft).

[d] HDV - Heavy Duty Vehicle (>8000 lb)
LDV - Light Duty Vehicle (<8000 lb)

There are a large number of private refuse collectors in the five-county area, estimated at 160 firms. The City of Denver, Department of Public Works, provides municipal refuse collection only to single and multiple family dwellings up to and including seven families in a single structure. There is extensive overlapping of refuse collection routes with as many as six refuse collectors in the same area. Twenty-eight disposal sites were being operated in the Denver region in 1971. Most are small with lifetimes ranging from 6 months to 5 years. Total remaining capacity, with no new sites, is equivalent to about 6 years. Some landfills are better operated than others but, according to DRCOG study reports, no landfills comply with the letter, or the intent, of state laws and regulations. Approximately 8,000,000 cubic yards of solid wastes were placed in landfills in the Denver region in 1971 with an unquantified amount in special purpose landfills, such as demolition rubble and toxic materials. Based upon population projections alone; i.e., assuming a present level constant rate of per capita solid waste generated, it is estimated that there will be 12,200,000 cubic yards per year by 1990. Assuming a 2-1/2 and 4-1/2 percent per capita increase per year, these figures become 19,500,000 and 29,700,000 cubic yards per year.

Major solid waste management planning for the Denver area was conducted through "Project REUSE" (Renewing the Environment through Urban Systems Engineering), a cooperative program of the Denver Regional Council of Governments and the Urban Drainage and Flood Control District, financed in part by an Urban Systems Engineering Demonstration

Program grant from the Department of Housing and Urban Development. The project included solid waste management and storm drainage and flood control, in an effort to identify and demonstrate concurrent approaches to improve the management and control of the two systems. Project REUSE has proposed a Resource Recovery and Recycling Center and support facilities that will reduce the amount of solid wastes that need landfill disposal 75 percent by 1986. By creating an Urban Systems Authority, as proposed by Project REUSE, the solid wastes collection and disposal system should be operated much more efficiently and economically than if the present set of events were allowed to continue.

IV. TRANSPORTATION EMISSION CONTROL MEASURES

"Transportation control measure" has been defined by the Environmental Protection Agency (EPA), to mean any measure such as reducing vehicle use, changing traffic flow patterns, decreasing emissions from individual vehicles, or altering existing modal split patterns, that is directed toward reducing emissions of air pollutants from transportation sources. Transportation control measures are required for any air quality control region where controls on stationary sources, combined with the Federal Motor Vehicle Control Program (FMVCP) placing emission standards on new cars, are inadequate to insure attainment and/or maintenance of the ambient standards.

To meet ambient air standards, many major urban areas must control emissions from motor vehicles to a greater extent than will be afforded by the Federal new car emission controls. Table 12 shows the general range of relative contributions of emission sources in U.S. urban areas.

Table 12

MIX OF EMISSION SOURCES IN URBAN AREAS, 1971(*)

Pollutant	Percent of Total Emissions		
	Automobiles	Trucks, Buses & Motorcycles	Stationary Sources
CO	77-87	8-10	3-15
HC	50-65	5-10	25-45
NO_x	40-50	8-13	37-52

*Source: U.S. Environmental Protection Agency

The Federal new car emission standards will eventually bring regional air quality within the standards in some areas, but numerous regions must develop transportation controls because new car emission reductions will never bring achievement of required air quality, or reductions will not be realized in the short term. Out of the 247 Air Quality Control Regions (AQCR) in the United States, State implementation plans to attain and maintain ambient air quality standards for 38 AQCRs were unable to provide adequate emissions reductions to meet the carbon monoxide and/or oxidant standards by 1975. Accordingly, these States have been required by EPA to develop transportation control and land use plans to meet ambient air quality standards. These 38 AQCRs include approximately 43 percent of the nation's population and 42 percent of the motor vehicles. During the period from June 15 to July 23, EPA announced transportation control plans for 36 cities.

The two broad categories of transportation controls that have been considered in State plans are 1) measures to reduce the number of vehicle miles traveled (VMT), and 2) measures to reduce average emission per mile of travel and/or reduce overall pollutant concentration build-up. In general, transportation control measures have been characterized by a number of factors which may serve as criteria in final control plan development. The appropriateness of a particular control alternative is thus determined by a heterogeneous group of factors such as the pollutant controlled, the magnitude and distribution of costs to implement, control effectiveness, as well as characteristics of the specific air quality control region such as topography, demography, climatology and institutional arrangements. For this reason, it is difficult to discuss control measures and their potential effectiveness in absence of the urban setting to which they are to be applied. Additionally, the degree to which specific control measures and aggregative strategies achieve emission reduction goals is highly dependent on public acceptance and adaptability of each measure. In turn, this public acceptance and reaction to control plans, and measures thereof, are conditioned by the manner in which the plans are presented to the public, and subsequently implemented, including administrative and enforcement components.

Over the longer term, the continual maintenance of ambient air quality standards will need to depend primarily on VMT, the amount of vehicle usage; it is not possible, however, to effect sizable region-wide VMT reductions by 1975 since most measures require long lead time to develop alternative means of travel. In contrast, those strategies that are designed to reduce emissions of individual vehicles will only have a major effect in the short term. Once the replacement of older, less-controlled vehicles with 1976 and later models is largely completed, these strategies will have only relatively small effects on air quality. There is a broad range of transportation control measures designed to exert their effect by reducing the total vehicle miles of travel. Some of these involve modifying travel patterns, either temporally or spatially; most measures, however, involve reducing the demand for motor vehicle travel.

In the complex urban environment, these various transportation measures are not independent, but are in many cases closely interrelated. Of particular significance, for example, is the interaction between those measures, such as gasoline rationing, that operate by restricting vehicle usage, and those, such as improved mass transit service, that operates through positive incentives to encourage usage of private vehicle alternatives. It appears to be the general case, based on limited test situations, that incentives to mass transit usage are not very effective unless accompanied by some restrictions on vehicular usage, and similarily, vehicle use restraints are not usually fully effective unless improvements or development of alternative transit modes are also made. Consequently, the selection of a transportation control strategy consisting of one or several compatible control measures requires a general analysis of control measure trade-offs, and their applicability in a specific metropolitan area.

In summary, the development of a transportation control and land use plan and selection of control measures for inclusion, requires the completion of a comprehensive analysis encompassing the following major tasks:

1. Analysis of the metropolitan region and setting for which the plan is to be applied. (Sections II and III of this impact statement)
    a. Development and analysis of a transportation data base
    b. Development and analysis of an air quality and emissions data base
2. Identification and analysis of alternative control measures.
3. Development of control measure application data including impact on air quality and feasibility/effect information.

4. Selection of a Control Plan consisting of one or more compatible control measures which will achieve and maintain ambient air quality standards (Section V of this impact statement)

5. Overall applicability and impact assessment of the control plan to include social, economic, and environmental media impact analysis (Section VI of this impact statement)

The remaining contents of Section IV address requirements number 2 and 3: Identification and analysis of alternative transportation control and land use plan measures, and selective control measure application to the Denver metropolitan area. Specifically, Part A identifies and provides a generic analysis of a wide range of candidate control measures that have been described in various studies, reports, and control plan developments. Part B provides a superficial evaluation identifying the apparent favorability of various control measures for application to the Denver AQCR without specific analysis. Finally Part C contains specific application data characterizing the individual control measures proposed for implementation in the Colorado Transportation Control and Land Use Plan developed for the Denver Metropolitan area. Analysis of these measures, therefore, in Part C, gives priority focus to transportation controls capable of being introduced by 1977 to reduce carbon monoxide and hydrocarbon emissions from light duty vehicles in high polluted areas of large metropolitan regions.

A. GENERIC CLASSIFICATION AND DESCRIPTION OF CANDIDATE CONTROL MEASURES

The two broad categories of transportation controls that have been considered in State plans are:

1. Measure to reduce the number of vehicle miles of travel (VMT)
2. Measures to reduce average emissions per mile of travel and/or reduce overall pollutant concentration build-up.

A third general category of controls, not aimed at mobile pollutant sources, that are associated with transportation control and land use plans are additional stationary source controls for hydrocarbons.

In certain metropolitan regions where transportation and land use controls have been required, stationary-source emissions of hydrocarbons are estimated to be a sizeable portion of the total emissions. Therefore, in the case of hydrocarbons, stationary source controls have been proposed as supplemental measures to vehicular controls to achieve the total hydrocarbon reduction requirements necessary to meet ambient oxidant air quality standards. Controls on non-vehicular hydrocarbon sources have also been advocated due to the relatively uncontrolled nature of many sources presently, and such control may result in a significant reduction potential.

Under the two broad categories of control measures for controlling mobile source emissions, a wide latitude of control approaches have been identified as candidate measures for regional application. Most transportation controls have only been considered recently for purposes of air pollution control, and thus a wide diversity of both discrete and overlapping measures appear in discussions of controls with absent agreement on classification systems, terminology and conclusions concerning the measures. According, the generic control measure identification and description in this report represent a compilation of state-of-the-art information on which there is little common agreement, and conclusions can only be tentative at this stage. The purpose of the descriptions is definitive, not assertive of any facts or point of view. Tables 13, 14, and 15 provide the more detailed compilation of information for the following general types of control measures:

1. Measures to Reduce VMT

a. Motor Vehicle/Traffic Restraints - These measures primarily consist of controls over parking and/or road use, whether by administrative action or pricing policy. For many transportation controls to be effective, motor vehicle restraints will be required at least in the short term. The impact of these measures on travel patterns include changes in modal mix by improvements in public transport and motor vehicle restraints. Only minor changes in trip generation or origin - destination patterns are expected, at least in the short term, with corresponding minor socioeconomic impact or changes in land use.

The overall impact on motor vehicle emissions is estimated to range from 5 to 25 percent, partially based on the severity of the restraints. Several motor vehicle restraints are administratively feasible, however, the mechanics of imposing motor vehicle restraints are less of a problem than gaining public acceptance.

b. Public Transportation Improvement - Public or mass transit may be defined to include rail and bus systems and a number of other means of travel such as taxi and carpools. Extensive review of evidence leads to the conclusion that public transport improvements alone hold little promise of major control effectiveness without corresponding measures to restrict or restrain private motor vehicle usage. Impact of travel patterns from public transit usage may include changes in modal mix, but little change in trip generation or origin — destination patterns — are expected in the short term. Motor vehicle emission reduction potential is variously estimated to be less than 5 percent.

c. Gasoline Limitations (rationing) - Gasoline rationing may be a highly effective approach in reducing vehicle miles traveled, but its feasibility for use without severe social and economic repercussions is highly dependent upon the availability of alternate means of transportation to permit the necessary mobility of the population. Administratively this measure is highly flexible to implement and adapt to changing circumstances. Public acceptance, as indicated in numerous surveys place this measure among those least desirable and potentially disruptive in the short term.

d. Land Use Controls/Planning - In the longer term, addressing urban transportation control problems through land use controls and planned public policies to minimize distances between activities and promote public transit accessibility are highly desirable. These measures may result in various travel pattern effects to include change in modal mix, change in origin-destination patterns, and changes in trip generation. These control measures, however, cannot be implemented with appreciable effects on vehicle emissions in the short term, and their intermediate and long term impacts are not known.

2. Measures to Reduce Emissions per VMT and/or Reduce Pollution Concentration Build-ups

a. Vehicle Inspection and Maintenance - Broadly defined inspection and maintenance measures encompass all, or in part, the following elements: 1) the inspection of in-use vehicles, 2) the identification of high pollutant emitters, and 3) some requirement for subsequent corrective action. Inspection appears to be a necessary prerequisite to corrective action for in use vehicles for two primary reasons: 1) to determine what corrective action needs to be taken, and 2) to reduce possible underservicing or overservicing. Therefore, inspection is an essential part of any effective program involving maintenance or retrofit. This control measure approach results in no significant changes in modal mix, trip generation or origin- destination pattern. It therefore has minimal impact on travel demand and hence minimal effect on social and economic activity and location of land use. Estimating effectiveness over time of inspection and maintenance is difficult, but it is possible to arrive at a broad range of initial emission reductions for in-use light duty vehicles. The potential range of emission reduction potential is from 10 to 25 percent, for light duty vehicles.

b. Retrofit in-use Vehicles - A retrofit approach can be defined as the addition of any device or system and/or any modification or adjustment made on a motor vehicle after its initial manufacture to achieve a reduction in emissions. The retrofit packages most commonly discussed for use in light duty vehicles include:

(1) Lean idle air/fuel ratio adjustment and vacuum spark advance disconnect.

(2) Oxidizing catalyst converter and vacuum spark advance disconnect.

(3) Airbleed to intake manifold.

(4) Exhaust gas recirculation and vacuum spark advance disconnect.

These systems have been developed by various automobile manufacturers and have a similar approach, i.e., combining modifications and adjustments to the carburetor, the distributor and vacuum advance. Existing systems can be installed relatively rapidly. Currently available industry type devices from automobile manufacturers appear to be able to reduce emissions by 20 to 25 percent for pre-1968 vehicles. Overall impacts of retrofit measures when applied to the light duty vehicle population as a whole are much more modest, and due to cost requirements, and uncertain impacts, their employment is limited to date pending more conclusive evidence of effectiveness with widespread application.

c. Traffic Flow Improvements - Traffic flow improvements include those traffic engineering measures that may be employed to reduce congestion, delays, idling periods, stops and starts; smooth traffic flow; and increase average vehicle speeds. The applicability of these techniques ranges widely based on the hierachy of transportation facilities, ranging from freeways to local streets, that serve urban areas. These controls have no effects on modal mix, and a possible increase in trip generation as a result of improved traffic flow. No impact on origin-destination patterns is projected. Impact on motor vehicle emissions attributable to these measures are estimated in various studies to be less than 20 percent, however, a problem arises in absolute quantification since these measures may have the counteracting effects of both reducing emissions per vehicle miles traveled and increasing total vehicle miles traveled.

d. Gaseous Fuel Conversion - Conversion of gasoline-powered motor vehicles to gaseous fuels have been considered, with three major types of fuels available as alternatives at the present time: 1) liquified petroleum gas, 2) compressed natural gas, and 3) liquified natural gas. In general these measures are considered only for large centrally maintained vehicle fleets, such as taxi and service vehicles, which may account for a high proportion of total VMT in urbanized regions. Conversions are of a short-term, interim character since new automobiles require increasing emission controls. Where applicable, gaseous fuel systems may account for up to 15 percent reduction in motor vehicle emissions. No significant travel pattern impacts are evident, but overall costs of fleet conversions imply a significant economic impact with a limited lifetime effect.

e. Bypassing through Traffic - These type of measures are primarily designed to: 1) shift vehicle miles of travel away from heavily used central city routes, and 2) smooth traffic flow by separating through traffic (which has been estimated to account for 5 to 20 percent of total traffic volumes in major central cities) and localized traffic. Both result in reduced emissions in high polluted areas of the central city, the first by redistribution, and the second by improving traffic flow and speed thereby reducing emissions per vehicle. These measures are typically assigned a low motor vehicle emission reduction potential, less than 5 percent. Most measures, however, requiring new construction are not implementable within five years. Modest bypassing may be possible through use of directive signs with more substantial bypassing requiring motor vehicle restraint type measures such as stickering of vehicles and associated prohibition of usage in certain urban areas.

f. Work Schedule and Administrative Changes - Work schedule changes such as staggering work hours may be instituted to reduce traffic congestion during rush hours, thereby reducing pollutant concentration build-ups but not total emission through VMT reduction. Use of a 4-day work week may additionally reduce total vehicle miles traveled. Other administrative change might include altered procedures for entrance and egress from parking facilities. These control measures are assigned a low emission reduction potential since increased leisure time would possibly generate additional recreational trips, offsetting the total impact on air quality. Administration problems and public acceptability compound the low overall predicted effective of this class of control measures.

g. New Vehicle/Engine Designs (alternative Technologies) - Several alternative engine technologies ranging from variations of the internal combustion engine to alternate fuel and engineering systems have demonstrated the ability to reduce pollutant emissions and meet standards levels on pilot scales. Several alternate technologies include diesel, electric and steam powered vehicles, the compound Vortex controlled combustion engine and others. The problem, however, is that these alternate designs cannot be implemented in the short term and face many uncertainties in the intermediate and long term with economic factors playing a dominant role. Prospects for mass production of these alternate technologies and associated service related industries render these options unworkable in the short term.

3. Other Supplemental Measures

a. Additional Stationary Source Controls for Hydrocarbons -

In developing control measures to reduce HC_x emissions from stationary sources, three major alternative approachs include:

(1) Determine the source of each specific reactive hydrocarbon and base source controls on the degree of reactivity.

(2) Classify the total AQCR inventory either reactive or non-reactive and control only the reactive hydrocarbons with best available control technology.

(3) Control the total AQCR hydrocarbon inventory with the best demonstrated control technology.

Hydrocarbons are a precursor of photochemical oxidants and theircontrol efforts are designed to prevent oxidant/ozone formation. The reactivity of organic compounds varies widely, with reactivity devoting the tendency of the organic pollutant to participate in oxidant/ozone formation. The choice of photochemically reactive and non-reactive definitions can have a dramatic effect on hydrocarbon control devices and in many cases, the need for any control at all. Potential HC_x stationary source measures summarized in Appendix B include those directed toward control of evaporative losses from petroleum products storage and handling, significant users of organic solvents and restrictions in the use and manufacture of paints and other surface coatings that contain photochemically reactive solvents.

Evaluative, state-of-the-art information on control measures governing the operation of major categories of hydrocarbon point sources is present in Appendix B.

b. Aircraft Emission Controls - Ground-based operations of aircraft may account for a significant component of the total emissions of carbon monoxide and hydrocarbons in a localized setting. Alternate control measures have been proposed to both reduce runway and taxi VMT, such as the use of tow vehicles and altered scheduling to minimize peak hour traffic pile-ups, and measures to reduce emissions per VMT through improved aircraft technology. These controls do not appear to be implementable in the short term due to administrative, legal, and institutional constraints. EPA, in a recent report to the Federal Aviation Authority (FAA) has recommended similar strategies as those referred to herein, to reduce aircraft emissions. These measures may provide effective, low cost reductions in HC and CO emissions in certain regions in the intermediate and long term.

As previously indicated, Tables 13 through 15 provide a compilation of generic information on candidate transportation control and associated control plan measures, utilizing the categories of controls just reviewed, with a more comprehensive listing of candidate individual control measures.

The information provided to characterize these candidate control measures covers a cross-section of characteristics and data, some highly definitive and quantitative, others subjective and qualitative, but all tentative and subject to further clarification.

The appropriateness of a particular control measure is dependent upon a number of factors to include the pollutant(s) controlled, characteristics of the control measure, characteristics of the specific region to which control measures are to be applied, and the aggregative or combined effects of several control measures implemented concurrently. The generic information provided in this section primarily relates to characteristics of the control measures, as identified in the margins of Tables 13 through 15. The factors identified include:

1. Number of AQCR proposing to employ the control measure as part of the required transportation control plan.
2. Costs, including direct private and public costs associated with strategy implementation and indirect costs occurring from induced actions, market price changes or adjustments resulting from the measure imposition.
3. Time required for positive implementation and/or purposeful lifetime of the measure.
    a. Primary Stage - refers to control measures to be undertaken as soon as technically possible.
    b. Maintenance Stage - control measures are those designed to bring about long-range system changes necessary to maintain air quality.

c. Contingency Stage - measures refers to those designed to be employed if the primary and contingency measures are not possible to implement. These measures are quite flexible, and may be employed in the short term for an indefinite period.

d. Secondary Stage - controls are measures of undetermined benefit or impact on air quality, but deemed to be worthy of additional examination.

4. Social impact/acceptability - this evaluation is based on degree of social and economic effect, disruptivity and demonstrated favorability in existing circumstances.

5. Emission reduction potential

6. Technical feasibility/applicability/availability - technical feasibility/availability apply to measures requiring equipment (hardware) and facilities. Applicability refers to control measures that are instituted through policy and procedural changes and not dependent on hardware.

7. Institutional feasibility is a subjective evaluation of the implementation potential based on legal, political, administrative and enforcement considerations, and time to affectuate such actions.

B. CONTROL MEASURES APPLICABLE IN THE DENVER METROPOLITAN AREA

Based on general characteristics of candidate transportation control and land use plan component measures, a cursory familarity with the Denver region, and existing Colorado plan evaluative information, a superficial appraisal of control measure applicability for potential use in Denver follows. At best, this listing provides a first stage refinement in control plan development based on gross favorability of various control measures to be refined through specific analysis. One overriding prerequisite used to superficially evaluate candidate control measures was the requirement that they be implemented by 1977.

The candidate control measures for implementation consideration in the Denver Metropolitan Region are:

1. Measures to Reduce VMT

    a. Motor Vehicle/Traffic Restraints

        (1) Parking restrictions
        (2) Vehicle free zones
        (3) Idling restrictions
        (4) Vehicle restrictions by type of vehicle or time of day
        (5) Pricing and tax policies such as vehicle use, gasoline and/or road user taxes
        (6) Special color licensing and/or stickering to prohibit vehicle use

    b. Public Transportation Improvement

        (1) Extension of existing systems
        (2) Operational and service improvements
        (3) Develop new bus systems/service
        (4) Develop new taxi service systems
        (5) Exclusive bus/carpool lane development
        (6) Carpool system development
            - Computerized locator service
            - Parking priviledges for carpools
            - Free liability insurance for carpooling

c. Gasoline limitation/rationing

d. Land use planning controls — short term measures

2. Measures to Reduce Emissions per VMT and/or Reduce Pollutant Concentration Build-Up

   a. Inspection and Maintenance of in-use Vehicles (Light and Heavy Duty Vehicles)

      (1) Visual inspection

      (2) Tune-up requirements

      (3) Idle exhaust measurement mode

      (4) Load exhaust measurement mode

      (5) Diagnostic maintenance

      (6) Mandatory maintenance

   b. Retrofit in-use Vehicles

      (1) Evaporative emission control systems

         - Vapor recovery systems
         - Adsorption-regeneration systems

      (2) Exhaust gas control systems

         - Thermal reactor
         - Exhaust gas afterburner
         - Exhaust gas recirculation with Vacuum Spark Advance Disconnect (VSAD)

      (3) Induction control systems

         - Airbleed to intake manifold
         - Lean idle air/fuel adjustment with VSAD

   c. Traffic Flow Improvements

      (1) Signal progress (traffic light syncronization)

      (2) Traffic responsive controls

      (3) Loading zone regulations

      (4) Improved freight and goods movement (e.g. consolidate trucking.

d. Work Schedule and Administrative Changes

   (1) Staggered work hours

   (2) 4-day, forty hour work week

   (3) Staggered egress from parking areas

3. Other Supplemental Control Measures

a. Additional Stationary Controls for Hydrocarbons

   (1) Dry cleaning operation controls

   (2) Degreasing operation controls

   (3) Organic solvent usage controls

   (4) Petroleum products storage controls

   (5) Gasoline transfer vapor control

   (6) Organic liquid loading control

   (7) Filling auto tank control

   (8) Paint and varnish manufacture controls

   (9) Graphic arts process controls

   (10) Architectural/surface coating controls

   (11) Animal rendering process controls

   (12) Agricultural open burning control

b. Aircraft emission controls

   (1) Tow service to reduce aircraft taxi length/time

   (2) Integrate scheduling to reduce take-off/landing delays

The following is a synoptic review of the major control measure categories that were excluded from the Candidate listing of potentially applicable techniques for 1977 Denver Plan development and a brief explanation for this exclusion:

1. Gaseous fuel conversion of fleet vehicles - eliminated because of the impending shortage of gaseous fuel and the rapid turnover rates of fleet vehicles with new vehicles complying with emission standards thereby making the impact of this approach insignificant in a short period.
2. Various traffic flow improvements - many of these control measures are already being employed widely throughout the Denver Area.
3. Bypass through traffic techniques - no major beltways or circumferential routes exists for effective short term employment
4. Retrofit catalytic converter measure - This measure required an adequate regional supply of unleaded gasoline suppliers state will not be available to the Denver area.

Other major control measure categories excluded from the list of candidate measure were eliminated from consideration for 1977 reduction achievement due to their intermediate to long term character, with no or minimal short term potential.

1. Land use planning/controls
2. New vehicle/engine design (alternate technologies)
3. Aircraft emission control - institutional feasibility also questionable.

C. CONTROL MEASURES PROPOSED FOR USE IN THE DENVER AIR QUALITY CONTROL REGION

This section provides a comprehensive analysis of the specific transportation control measures comprising the 1977 Colorado Transportation Control and Land Use Plan. The analysis includes a descriptive characterization of the following control measures or strategies:

1. Vehicle Miles of Travel Reduction Measures
    a. Designation of mandatory bus/carpool lanes
    b. Limitation on the construction of future parking facilities
    c. Removal of on-street parking
2. Semi-annual Inspection and Maintenance
3. Airbleed Retrofit for pre-1968 Vehicles
4. High Altitude Modification
5. Improvement in Public Transit
6. Bikeway Development
7. Stationary Hydrocarbon Controls
8. Gasoline Limitation (rationing)

The description of these component control plan measures focuses on general characteristics with a consideration of their application to the Denver region in terms of the following characteristics:

1. General Control Measure Identification
2. Air Quality Impact
3. Time to Implement
4. Expected Cost to Implement, both Direct and Indirect
5. Institutional Feasibility
6. Relationship to other Plan Control Measures
7. Social Impact/Acceptability

The aggregative impact of the Transportation Control Plan and more specific assessment of the social, economic and environmental impact of the specific component measures is contained in Section VI of this Draft Environmental Impact Statement.

1. Vehicle Miles of Travel (VMT) Reduction Measures:

In addition to direct gasoline limitations, three control measures have been incorporated in the Colorado Transportation Control and Land Use Plan to directly reduce vehicle miles of travel. These include:

a. Designation of mandatory bus/carpool lanes
b. Limitation on the construction of future parking facilities
c. Removal of on-street parking in the core area

The State recognizes that public transportation systems alone cannot reduce carbon monoxide levels significantly unless vehicle restraint methods are also employed. With the availability of a viable alternative such as improved public transportation, successful reduction of carbon monoxide and hydrocarbon levels can be expected. Thus these control measures are proposed as components in the overall plan to encourage the usage of proposed public transit systems, thereby enhancing the aggregative effectiveness of each.

a. Air Quality Impact - According to EPA, Region VIII, it is estimated that implementation of these three VMT reduction measures will achieve a reduction of 8 percent carbon monoxide and 6.9 percent hydrocarbon emissions over base year 1971 levels in 1977. It must be emphasized that any measure to restrain the use of the automobile must be accompanied with viable transportation alternatives. The proposed short term improvements in mass transit and bikeway development are thereby determinant parameters in the effectiveness of VMT reduction measures, and likewise the reverse is true.

b. Time to Implement - These VMT reduction measures are to be fully implemented by December 1, 1974.

c. Technical Feasibility - Implementation of the proposed VMT reduction measures faces no technical problems, although selection from alternative trade-offs in designation of mandatory bus/carpool lanes and areas to restrict parking activities require careful planning to achieve maximum desired effectiveness. For example, mandatory bus/carpool lanes comprise lanes on surface streets and/or freeways which would be open only to buses, so that the bus network would be efficient, convenient and speedy. Exclusive bus lanes are directed related to the concept of key street parking removal in that certain designated streets will have the parking removed so that lanes can be constructed for buses in their place. It has been demonstrated that acquisition of existing lanes of traffic for bus/carpool lanes may cause greater downtown congestion. Therefore it is suggested that exclusive bus lanes should be constructed on the portion of the street which is not now used for vehicle lanes. Removal of on-street parking could provide for the exclusive bus lanes. Thus, these VMT reduction measures are not only affected by other control measures, but they may interact synergistically (e.g. bus/carpool lanes and parking restrictions) to achieve a greater combined effectiveness than would either measure alone.

d. Expected Cost to Implement

(1) Direct Cost - No direct cost estimate is avail-

able for implementation of these VMT reduction measures. Cost required in terms of equipment and facilities is minimal. Control agency costs in the form of public education to promote citizen participation, and other efforts to include carpool locator service development and enforcement of traffic bans may also be required based on the control measure implementation approach taken.

(2) Indirect Costs - Public transit fare costs and minor schedule changes in citizen travel requirements may be required in the short term, but overall cost impact may be offset by private vehicle cost savings and related factors.

e. Institutional Feasibility

(1) Action Required - Air Pollution Control Agency implementation of these measures will require cooperative planning and program development with city and regional governmental authorities with jurisdications over Denver metropolitan area zoning, highway and parking services and public information channels.

(2) Administration and Enforcement - City and regional law enforcement agencies and highway service personnel cooperation with program administration and enforcement will be required, in addition to other community service agency involvement such as the Regional Transportation District.

f. Relationship to Other Control Measures - These VMT reduction measures both interact with each other (e.g., parking restrictions and bus/carpool lane development) and with other measures to include 1) improvement in public transit, 2) gasoline limitation and 3) bikeway development.

g. Social Impact/Acceptability - A survey of public attitudes on transportation control measures (See Appendix A) conducted in seven metropolitan areas, including Denver, shows that the most acceptable proposals for controlling automobile pollution are prohibiting traffic/parking in central business districts and creating bus/carpool lanes. On the other hand, the prospects of joining or organizing a carpool were not high among non-carpool riders. Acceptability of these VMT reduction measures will be highly dependent on improvements in the RTD, Early Act Program of public transit.

2. Semi-annual Vehicle Inspection and Maintenance of Light Duty Vehicles

The inspection/maintenance program is aimed at reducing emissions from in-use vehicles by insuring that the emission levels of those vehicles are not permitted to deteriorate, through inadequate or improper maintenance, substantially beyond the levels of new vehicle emissions. The inspection/maintenance program being proposed can accomplish emission reductions only to that extent that voluntary maintenance is inadequate in maintaining the vehicles in good condition.

All light duty motor vehicles registered in the region will be inspected and tested with an idle test at least twice per year at a franchised garage inspection station. Spot checks will be conducted to insure against post-inspection adjustment or modification. Failure criteria will be established for the first year's inspection cycle. Those vehicles failing the test will be required to undergo corrective maintenance. A chart prepared during the test will be given to the owner to assist his mechanic in correcting the vehicle's problem.

a. Air Quality Impact - According to EPA Region VIII, it is estimated that implementation of this measure will result in a reduction of 7.4 percent carbon monoxide and 2 percent hydrocarbon emissions over base year 1971 levels in 1977.

The above conclusions regarding the inspection/maintenance approach apply specifically to the types of vehicles that are currently a part of the in-use vehicles found in the Denver Air Quality Control Region. It is not possible at this time to define the effectiveness which the inspection/maintenance program will have if applied to future model year vehicles using substantially different types of emission control systems.

b. Time to Implement - This measure is to be fully implemented by December 1, 1975.

c. Technical Feasibility - Equipment is available and there is enough experience in this field to determine an appropriate test procedure. Studies are required to determine the most efficient and adaptable procedure to meet regional needs and control plan measures.

d. Expected Cost to Implement

(1) Direct Cost - The idle inspection is anticipated to cost $6.00 per test with maintenance averaging $35.00 per vehicle. It is anticipated that the emissions test will be performed by the private sector and capital equipment costs will therefore be regained by the $6.00 emission test fee.

(2) Indirect Costs - Requirements for mechanic training and studies to be established at the State level toward certifica-

tion of devices and development of installation procedures and testing, are primary indirect costs of this measure.

e. Institutional Feasibility

(1) Action Required - Passage of enabling legislation for emission inspection for the region. Securing of capital to construct system. The Clean Air Act states that Federal support may be provided for up to two-thirds of the cost of constructing and operating the system. Pressure must be brought to bear on Congress to authorize expenditure of funds to support the Regional program. This requires State/Federal lobbying by the region.

(2) Administration and Enforcement - Although the State Department of Motor Vehicles and the Metropolitan police force probably have the authority to enforce this measure, it is the opinion of the Air Pollution Control Division that the final authority should rest with the division and be delegated to other agencies as required. Of immediate concern is the establishment of the organization or organizations necessary to implement an effective on-going, cooperative interagency program. This initial concern can be alleviated through a two-phase program occurring over the next two years (1973 and 1974). The program proposed herein may be viewed in the following three phases:

Phase I - Acquisition of State staff, use of commercial testing facilities for data acquisition and adoption of legislative enabling authority.

Phase II - Implementation of interim maintenance and inspection program.

1. The interim program consists of three major elements:

a. Inspection and testing of vehicles for compliance with emission control regulations and standards for cars that require a change in registration.

b. Mandatory adjustment and maintenance of vehicle emission-related systems coordinated with the safety inspection program.

c. Regulated control of voluntary tune-ups and emission-related repair.

Phase III - Implementation of idle test program in the private sector for all cars in the Denver Air Quality Control Region (possibly in select other air quality control regions) and certain other vehicle use control requirements statewide.

f. Relationship to Other Control Measures - Interrelated with light duty vehicle retrofitting: 1) airbleed system and 2) high altitude modification.

g. Social Impact/Acceptability - Public surveys, according to the Colorado Air Pollution Division show this to be an acceptable measure. The projected cost of $6.00 will mean $12.00 for a semi-annual system. Reaction to this cost will be less favorable, particularly in view of the $4.58 average yearly cost deemed to be acceptable in a Denver survey (Appendix A-6).

3. Airbleed Retrofit for Pre-1968 Vehicles

The retrofit approach goes beyond the attempt made by the idle inspection/maintenance program to keep in-use vehicles at minimum levels consistent with their original design. In the proposed retrofit approach, the goal is to reduce an in-use vehicle's emission below its "well-maintained" levels, through adding new emission control devices or through modifying the original design to achieve lower emissions. The airbleed to intake manifold retrofit device is an air valve that enables the air-fuel ratio to be increased by metering additional air to the intake manifold in accordance with intake manifold vacuum. The effect is one of reducing HC and CO levels, possibly with severe overall increase in NO_x levels.

a. Air Quality Impact - According to EPA, Region VIII, it is estimated that full implementation of this measure will result in a reduction of 4 percent carbon monoxide and 1 percent hydrocarbon emissions over base year 1971 levels in 1977. In general, tests conducted on this system for EPA indicate an expected reduction potential of 21 percent hydrocarbons and 58 percent carbon monoxide emissions from total emissions of vehicles tested.

b. Time to Implement - The airbleed retrofit measure for pre-1968 light duty vehicles is to be fully implemented by July 1, 1976. In general, certification, manufacture, and installation of retrofit devices will require at least twenty-four months from the establishment and exercise of legal authority.

c. Technical Feasibility - This mechanical retrofit is technically feasible, with tests conducted for EPA showing a reliability in use to be approximately 75,000 miles before total failure. Availability of devices from manufacturers would have to be investigated.

d. Expected Cost to Implement

(1) Direct Costs - The installed cost of the airbleed system tested for EPA is estimated to lie in the range of $56 to $64.

A fuel economy improvement of 4 percent is reported to be associated with the use of this device, which would reduce operating costs by $1.20 per 1,000 miles of operation.

(2) Indirect Costs - Several indirect costs may result including:

1. Possibly some increase in NO_x emissions with vehicle usage.
2. Maintenance cost estimated for EPA to be about $7.00 per 12,000 miles of vehicle travel.
3. Some minor deterioration in drivability judged to be "accaptable".
4. Mechanic training for maintenance/inspection. Proper installation and maintenance are essential, however, and this measure must be implemented in concert with mechanic training programs and periodic emissions inspection system.

e. Institutional Feasibility

(1) Action Required - The inspection system will provide the means to check installation of devices. At present no system exists to provide the necessary training of mechanics for installation. Presumably this and the sizeable task of establishing manufacturing and marketing facilities would fall to the companies whose devices were approved. These three institutional needs will be the major obstacles to implementation. Overall, according to the Colorado Air Pollution Control Division, the actions required are: 1) passage of enabling legislation for emission inspection for the region and 2) securing of capital to construct system. The Clean Air Act states that Federal support may be

provided for up to two-thirds of the cost of constructing and operating the system. Pressure must be brought to bear on Congress to authorize expenditure of funds to support the Regional program. This requires State/ Federal lobbying by the region.

(2) Administration and Enforcement - Although the State Department of Motor Vehicles and the Metropolitan police force probably have the authority to enforce this measure, it is the opinion of Colorado Air Pollution Control Division that the final authority should rest with the division and be delegated to other agencies as required. One enforcement approach may be denial of vehicle registration by the Colorado Department of Highways if devices are not installed or maintained.

f. Relationship to Other Control Measures - Airbleed retrofitting directly interacts with the proposed inspection and maintenance of light duty vehicles.

g. Social Impact/Acceptability - The relatively high cost of this control device ($56 to $64) will not meet with favorable public approval from that portion of the Denver region population with pre-1968 vehicles. Estimates indicate this number to be about 30 percent of the vehicle population in Denver. This cost imposition is compounded by the lower absolute value of pre-1968 vehicles, thereby making the added cost a relatively large addition, especially to families with lower incomes more likely to own these vehicles.

4. High Altitude Modification and Tuning Specification for 1968-1975 Vehicles

The high altitude mandatory tune-up and/or modification program is aimed at reducing emissions from in-use vehicles through ensuring that the emission levels of those vehicles included are tuned or modified to compensate for the altitude effect. According to Colorado State Health Department officials, compensation for the adverse effects on combustion efficiency of decreased air density at high altitude may be accomplished in at least six ways: (a) by an altitude controlled air port or valve for admitting more air; (b) by a variable fuel orifice for restricting fuel flow; (c) by pressure reduction in the carburetor float chamber for restricting fuel flow; (d) by throttling the air supply to maintain constant air density; (e) by a pressure regulated carburetor power metering valve for preventing rich mixtures; and (f) by a barometrically controlled vacuum spark advance for maintaining mean effective cylinder pressure. Pre-1968 vehicles, except in California, do not lend themselves to the modifications which must be performed to claim reductions in exhaust emissions. All these measures effect the combustion knock tendency of the engine class. These modifications would also nullify the use or effectiveness of the vacuum spark advance disconnect (VSAD) device as found on many of the existing members of this engine class.

a. Air Quality Impact - According to EPA calculations, it is estimated that implementation of this measure will result in a reduction of 9.4 percent carbon monoxide and 2.5 percent hydrocarbon emissions over base year 1971 emissions in 1977.

b. Time to Implement - This measure is to be fully implemented by July 1, 1976.

c. Technical Feasibility - Preliminary investigations indicate a very high technical feasibility with the majority of components being "off the shelf" items. A possible consequence of application of any of the devices would be an increase in the demand for higher knock-rated fuels. The actual emission reductions that can be achieved over time through an altitude tune-up and modifications program will depend upon the rate and extent of emission control deterioration between the required tune-up events. A study of this factor is being proposed under the contractor obligations, but sufficient data are not yet available to define the influence of deterioration on the average reductions achievable by a tune-up program over time.

d. Expected Cost to Implement

(1) Direct Costs - It has been estimated that the cost of altitude tuning would not vary significantly from the current annual average per vehicle of $30 in the Denver Air Quality Control Region. The cost of vehicle modification is a one time occurrence and is expected not to exceed $20 per vehicle installed. Possible options are estimated to range from $20 to $35 per vehicle installed.

(2) Indirect Costs - A consequence of applying any of the above compensation measures on the indicated population class would be a possible increase in demand for higher knock-rated fuels. Combustion knock is a function of the following: (a) combustion temperature, (b) ignition lag time, (c) combustion chamber design for optimum flame speed, (d) optimum spark advance, (e) compression ratio of the engine, and (f) octane rating of the fuel being used. All the listed compensating measures affect the combustion knock tendency of the engine classes described. It is possible, therefore that an indirect cost may be an

increase in the price of no-knock gasoline. Additionally, tests have revealed that the implementation of a required altitude tune-up and modification program strategy could result in significant reductions in HC and CO emissions, while nitrogen oxide (NO_x) emissions may increase an average of 30 percent.

A final indirect cost will result in training mechanics to install and maintain such devices. On the opposite side, this measure may increase fuel efficiency, thereby decreasing total gasoline costs to users.

e. Institutional Feasibility

(1) Action Required - Amendment of the regional vehicle and traffic laws to provide the necessary legal authority. Devices must be approved and certified, and mechanics trained in installation. Determine available supply of "off shelf" items and necessary manufacturing. Induce manufacturers to produce devices in sufficient quantities.

(2) Administration and Enforcement - Administering the program through the Highway Department will permit enforcement through denial of vehicle registration.

f. Relationship to Other Control Measures - This measure related to the semi-annual inspection and maintenance proposal and mechanic training to meet personnel requirements.

g. Social Acceptability - Of the available or proposed retrofit options, the high-altitude modification would probably have the highest level of acceptability because of the increased fuel efficiency and the direct approach to a problem peculiar to high-altitude areas.

The relatively small cost associated with this measure for 1968-1974 vehicles enhances its acceptability.

5. Improvement in Public Transit

Improvement in public transportation are based primarily on the Regional Transportation District (RTD) Early Action Program (EAP). The EAP is a key element in the overall RTD plan. It provides immediate improvements and also begins to encourage the "transit habit". The Early Action Program deals with four elements of implementation; the Early Action Bus program, acquisition of rights-of-way, development of parking facilities, and preparation of detailed community impact construction standards. Local, express and regional bus service will be important elements of the improved public transit system, planned to be implemented at the earliest possible date following the successful 7 September 1973 public referendum, by adding new routes and increasing frequency on existing routes.

Specifically, RTD plans to purchase 115 new buses as rapidly as possible to increase the level of bus service on existing routes and establish service on new routes. The program will provide an increase of about 270 route miles within the district, representing an increase of about 60 percent in bus service. Daily bus miles will increase by some 33 percent - to about 32,000 miles. Specific service improvements of the Early Action Program will be increased service on established routes and initiation of new routes. Since the automobile will still play a role in delivering passengers to the public transportation system, and particularly to express bus and regional bus access, park-and-ride facilities are proposed. The facilities will serve as automobile intercepts where private vehicles will be parked and public transit boarded. Additionally, bus shelters are to be constructed throughout the Denver region.

a. Air Quality Impact - In general, a bus program to be effective, must fulfill at least three criteria:

1. It must replace a significant number of cars.
2. It must be convenient for the user (i.e., provide transportation at frequent intervals to and from locations at a short distance from user destination and do so under reasonably comfortable conditions).
3. It must be inexpensive compared to driving a private car.

A sufficient number of buses must be provided and the routes carefully selected to induce commuters to leave their cars in parking lots provided for them at the outskirts of the city and serviced frequently by express or shuttle buses.

It is not clear what direct emission impacts will occur from the RTD system in the short term, particularly during the actual construction of facilities related to the overall public transit network. Several factors, however, indicate the importance of this plan element as it interacts with the overall transportation and land use plan. Presently, in Denver, the occupancy rate in commuter cars is estimated to be 1.3 to 1.6 persons/car. An average bus seats from 45 to 50 people. Thus one full bus load can replace 30 to 35 cars. During the work week, according to the Colorado Division of Air Pollution Control, rush traffic is experienced for at least 1-1/2 hours in the morning and as long at night. Each bus can make a round trip in that time and a bus produces only 2-1/2 times more pollutants than a car. Thus, increased bus ridership implies an emission reduction potential associated decreased usage of private vehicles.

On the other hand, Wirth-Berger Associates, in an interim environmental assessment of the RTD plan (R.T.D. Plan: An Environmental Assessment, June 1973), states that, for the Denver Central Business District, a heavier concentration of traffic will occur due to the transit network, resulting in a slight relative decline in air quality in the downtown area. Therefore, in total, an assessment of the direct emission reduction potential of improved public transportation must balance the reduction in emissions associated with decreased private automotive usage, with the increase in potential emissions associated with increased downtown traffic concentrations.

The program to improve public transit, however, is vital because it, in itself, provides the major alternative to the private motor vehicle. The early action program with its provision for peripheral parking, exclusive bus lanes, and express service fills a void in regional transportation that currently exists. Other control measures to improve air quality in the Denver region that are aimed at restricting vehicle usage and VMT are not fully effective unless improvements or developments of alternative transit modes are made. Consequently, the direct emission reduction potential of improved mass transit may be insignificant compared to the indirect effectiveness of this measure reflected in the emission reduction potential of VMT control measures such as bus/carpool lanes, parking restrictions and gasoline rationing.

b. Time to Implement - The RTD, Early Act Program is to be implemented at the earliest possible date following the successful public financing referendum 7 September 1973, and will continue through the 1977 transportation control plan horizon. The addition of 115 new buses is scheduled to occur before May 31, 1975.

c. Technical Feasibility - No technical problems are evident, although many aspects of the improved transit system have not been specifically detailed, the technical aspects of program, including equipment, facilities, and services proposed are feasible to implement.

d. Expected Cost to Implement

(1) Direct Costs - The capital cost of the Early Action Bus Program is estimated at $17,675,000 in 1972 dollars. Components of this cost include 115 new buses, 100 shelters, a new bus storage and maintenance facility, plus acquisition of existing transit systems as appropriate.

The annual operating cost of the Early Action Program is estimated at $10.4 million in 1972 dollars, or about 42 percent greater than at present. Operating costs for bus service, increasing at about 5 1/2 percent per year can be expected to reach about $12.6 million in 1974.

(2) Indirect Costs - Right-of-way acquisition and physical facility construction will result in alterations of present patterns of activity in the region. Indirect costs associated with the construction of facilities may range from short-term highway congestion to inconvenience associated with construction activities. The community

impacts associated with the Early Action Program and the longer term Personal Rapid Transit System to be completed by 1984, will in part, depend upon:

- How the public will be informed of traffic routing changes required by the construction of the system.
- How noise problems related to construction will be handled.
- How landscaping will be replaced. It may be desirable for the district to establish its own tree farm, or at least sources of supply, early in the program.
- How the need to maintain access to adjacent properties during construction program will be handled.

e. Institutional Feasibility

(1) Action Required - On 7 September 1973 residents of the Denver metropolitan area, in public referendum, approved financing of the RTD system, through a half-cent sales tax to finance improved bus service and a rapid transit network for the six-county District. This demonstration of public acceptance and appeal of the plan should facilitate implementation action requirements to include a number of EAP measures such as:

- acquisition of or integration with existing transit service.
- acquisition of additional bus equipment and facilities.

(2) Administration and Enforcement - No major enforcement requirements are implied by the plan. The RTD will administer the program, requiring integration with existing transportation related public agencies at the City, State, and Federal levels to meet financing and other operational objectives.

f. Relationship to Other Control Measures

(1) Vehicle mile reduction measures

    (a) Bus/carpool lanes
    (b) Parking lot construction limitations
    (c) On-street parking limitations

(2) Gasoline limitations and rationing

g. Social Impact/Acceptability - High public acceptability of this measure was demonstrated through the 7 September 1973 public referendum resulting in approval of a financing plan to implement the RTD proposed transit plan, including components that will enhance mass transit as recommended in this measure. A public attitude survey (Appendix A-11) in Denver revealed that up to 35 percent of the respondents might dispose of 1 automobile if public transportation were available.

6. Bikeway Development

Included in the RTD Early Act Program to improve public transportation is a reduction for voluntary usage of a planned bikeway network for the immediate Denver metropolitan area. The bikeway plan proposes a pilot bicycle route from an outlying residential area to the heart of downtown Denver. This pilot route will give an indication of how the total system might be used. It is expected that the use of this pilot route will point out the desirability of developing the total bikeway system. This total system of 164 miles of planned bicycle routes, complete with its own system of signs, will provide the commuter bicyclist with efficient point to point travel. The goals of the bikeway plan are (1) to assess bicycle demand for routes, (2) to develop a bike route plan, (3) to estimate costs, and (4) to develop implementation phases. The complete plan would produce 64 city bicycle routes totaling 164 miles providing efficient point to point travel.

a. Air Quality Impact - Bicycle registrations in 1971 totaled 32,000 in Denver and an estimated 100,000 are not registered. Potential reduction in emissions is minimal, possibly up to 1 percent of 1971 uncontrolled emissions. The potential reduction for the entire proposed system is unknown at this time because of the voluntary nature of the project. Maximum impact is dependent on voluntary usage and system completion.

b. Time to Implement - A pilot project is complete. Installation of the bicycle network and bus transfer system are contingent upon public demand and Denver City Council authorization. It is estimated that bikeway development could be completed by 1975.

c. Technical Feasibility - No technical problems are envisioned with the proposed bikeway measures

d. Expected Cost to Implement

(1) Direct Cost - Total cost of the system is estimated at $800,000 to $900,000. Bicycle license fees are proposed at $5.00.

(2) Indirect Cost - Yearly operational and maintenance costs are estimated at $100,000. Enforcement of riding laws, public safety measures and interaction with vehicle traffic will likely be required to increase.

e. Institutional Feasibility

(1) Action Required - Effective and efficient management require:

1. Amend the "Revised Municipal Code" and adopt new legislation for safety and welfare.
2. Establish 64 bicycle routes as proposed.
3. Provide good bike route design.
4. Enforce riding laws.
5. Monitor system and keep plan flexible.

(2) Administration and Enforcement - These may be accomplished through cooperation with local law enforcement agencies with financial support to meet increase service requirements.

f. Relationship to Other Control Measures - Mass transit improvements including the RTD Early Action Program.

g. Social Impacts/Acceptability - Based on the 1971 registration of bicycles (32,000) and the estimated 100,000 that are not registered, this measure appears to have a large audience of favorable acceptable. Additionally, the low cost and low disruption to present transit patterns adds to its favorable impact and acceptability.

7. Stationary Hydrocarbon Controls

A comprehensive set of regulations for the control of hydrocarbon emissions from stationary sources in the Denver region have been proposed to supplement the transportation control measures selected. Major source categories to be controlled by the proposed regulation include:

1. Dry cleaning operations
2. Degreasing operations
3. Organic solvent usage
4. Petroleum products storage
5. Organic liquid loading
6. Gasoline transfer vapor control
7. Filling automobile tanks
8. Paint and varnish manufacturing

a. Air Quality Impact - According to EPA, Region VIII, it is estimated that 24 percent of the hydrocarbon emissions over base year 1971 levels in 1977 will be achieved by this measure. This represents 40 percent of the total amount of hydrocarbon emission reductions required to meet ambient air quality standards in the Denver AQCR in 1977.

b. Time to Implement - The compliance schedules required by the proposed regulations vary by type of source category to be controlled and control process, ranging from January 31, 1974 to May 31, 1976.

For information on the following factors:

d. Expected Cost to Implement

(1) Direct Costs

(2) Indirect Costs

e. Institutional Feasibility

(1) Action Required

(2) Administration and Enforcement

f. Social Impact/Acceptability

see Appendix A of this Environment Impact Statement, titled "Additional Source Controls for Hydrocarbon Emissions".

This section provides evaluative state-of-the-art information on control measure options for eight major classes of stationary hydrocarbon. The information provided for each HC source class includes: (1) control(s) description(s); (2) pollutant reduction potential; (3) time to implement, (4) technical feasibility; (5) expected cost to implement, both direct and indirect; (6) social impact/acceptability; and (7) location affected — availability/applicability. The following classes of stationary hydrocarbon sources are examined:

1. Degreasing operations
2. Dry Cleaning operations
3. Graphic arts operations
4. Industrial surface coating
5. Petroleum refineries
6. Gasoline sales and distribution
7. Petroleum products liquid storage
8. Petrochemical manufacture

8. Gasoline Limitation (rationing)

It is proposed that a limitation on gasoline sales at fiscal year 1973 levels to be effective on July 1, 1974, and a 31 percent reduction in VMT attained by the same method to be effective on May 31, 1977 will be implemented in the Denver AQCR.

The 31 percent reduction is not mandated in the proposed regulations. The State is required by January 1, 1977 to evaluate the reductions in VMT achieved through other strategies prior to that date, and project the necessary VMT reduction to be achieved through gasoline limitation. The 31 percent represents EPA's best estimate of this required reduction based on current data.

The statement of a requirement for a 31 percent VMT reduction is somewhat misleading when viewed in the context of the gasoline sales limitations to be imposed earlier. The 31 percent is a reduction from projected 1977 levels rather than 1971 levels. The sales limitation on gasoline should effectively stop growth in VMT, hence the actual reduction from current levels should be somewhat less than 31 percent.

Gasoline limitation was selected because it was originally included in the Colorado submittal as one of the State's transportation control measures and seemed most practical particularly in view of its low cost of implementation. Furthermore, implementation of the strategy to account for a significant VMT reduction might not be necessary. The required VMT reduction may be achieved by the State through other means such as mass improvements. The relative ease of implementation of gas limitation compared to many other strategies makes it attractive in a situation such as Colorado's where there is a significant chance that it may not have to be implemented. This measure, therefore, will serve primarily as a contingency control in 1977 to be implemented to a degree necessary to complement the effectiveness of other control plan measures, if necessary, to meet ambient air quality standards for CO and HC.

a. Air Quality Impact - According to EPA, Region VIII, it is estimated that gasoline limitation will result in a reduction of

3.8 percent carbon monoxide and 3.3 percent hydrocarbon emissions over base year 1971 levels in 1977.

Stated differently, gasoline limitation is to serve primarily as a contingency measure in 1977, only to be employed to a level necessary to achieve required emission reductions that the other control plan measures have not been able to achieve in meeting ambient standards. Gasoline sales limitations at fiscal year 1973 levels will be effectuated July 1974, but the imposition of further limitations May 1977 is contingent upon the air quality in the Denver region at that date. Therefore, the emission reduction potential estimates above apply specifically to EPA's estimate of the degree of gasoline rationing required in the Denver setting, and not with respect to the overall effectiveness of gasoline rationing as a emission control measure.

In general, gasoline limitation and resulting VMT reductions may lessen congestion in the downtown area, and serve to encourage carpooling, bicycle utilization and the use of transit. Therefore, the overall effectiveness of this measure would be reflected to some degree, in the effectiveness of these other control plan components that are impacted.

b. Time to Implement - This is a flexible measure that can be implemented relatively rapidly (within 6 months). In the proposed Denver Transportation Control and Land Use Plan, gasoline sales limitations will be effectuated July 1, 1974, and further limitations imposed May 31, 1977 based on emission reduction requirements at that time.

c. Technical Feasibility - Procedures for implementing this control measure are available, relatively flexible, and short-term in requirement of time to affectuate. Additionally, procedures have been developed by the U.S. Office of Emergency Preparedness, and World War II experience is well documented.

d. Expected Cost to Implement

(1) Direct Costs - This cost is primarily dependent upon implementation procedures, and the degree of gasoline limitation required by 1977 to meet ambient air quality standards. Implementation costs to the control agency are minimal. The primary incidence of cost, that imposed to the private vehicle and transit user, at best can be estimated based on a range of sales limitation levels, and costs are highly dependent upon the availability of substitute transit modes, such as public transit. Section VI of this draft Environmental Impact Statement has a more comprehensive assessment of potential costs. The Colorado Division of Air Pollution Control estimated that many of the alternative control measures in the Plan would probably require more cost and capital expenditure prior to implementation than gasoline limitation, and similarily would require more lead time.

(2) Indirect Costs - Again, the magnitude and incidence of costs are dependent on many variables related to the specific Denver region, and the degree of gasoline limitation required. Generally, gasoline prices may increase as well as prices of goods and services that are transit or freight dependent. Altered mobility may affect activities of citizens. These factors are assessed in Section VI.

e. Institutional Feasibility

(1) Action Required - In order to implement gasoline sales limitations at retail outlets to base 1973 sales levels the State will be required to establish a detailed accounting system of gasoline sales through retail sales outlet distributors. Further, the State will need to monitor compliance with the limitation on total gallonage established and later revise the required limitation to meet ambient air quality standards in 1977.

(2) Administration and Enforcement - This will depend upon the specific method and extent of limitation required by 1977. Control agency requirements will be minimal.

f. Relationship to Other Control Measures - Interrelated effectiveness and impacts with: mass transit improvement, bikeway development, and vehicle mile reduction measures to include bus/carpool lanes and parking restrictions.

g. Social Impact/Acceptability - Nationwide, gasoline rationing or limitation is one of the most unacceptable control measure proposals, as demonstrated in the social attitude survey summarized in Appendix A. In the survey, the following responses to gasoline rationing were received:

Gasoline rationing	Population
Unacceptable	83.8%
Neither Acceptable nor Unacceptable	6.4%
Acceptable	9.8%

To the extent that "essential" travel is not restricted the public may view rationing merely as an inconvenience. Beyond this degree, severe social and economic consequences may result, thereby sharpening public disapproval. To a large degree several factors will influence the overall impact and social acceptability of this measure to include:

1) Degree of limitation in 1977 based on other control plan measure effectiveness
2) Availability of cheap, quick and accessible public transit
3) Control agency implementation approach and public education on this measure.

V. ALTERNATE TRANSPORTATION PLANS FOR DENVER

States were required to submit implementation plans by January 20, 1972 that contained control strategies demonstrating how the national ambient air quality standards would be achieved by 1975, except that under certain circumstances the deadline for meeting the standards could be extended for a period not to exceed two years. A recent decision by the U.S. Court of Appeals for the District of Columbia Circuit clarified the procedures by which such an extension could be granted. Under this decision, the State of Colorado was required as a first step to submit a transportation and land use control plan that would show attainment of the standards for photochemical oxidants/hydrocarbons and carbon monoxide as expeditiously as practicable but no later than May 31, 1975. In response, Colorado submitted what it considered to be the most feasible plan to achieve this objective plus supporting information to show that the plan could not be implemented by that date, and requested the two-year extension. In reviewing this plan, EPA considered the feasibility of alternative control measures and also concluded that the standards could not be met by 1975 even with the combined use of all reasonable strategies, and that an extension would be required for the Metropolitan Denver Region. Acting on this decision, the State submitted a new plan, comprised of a revised 1975 plan plus three additional strategies, which it believed was adequate to meet the standards by 1977. EPA, however, in its review of this 1977 plan, felt that an additional measure to reduce VMT would be necessary and proposed a limitation on gasoline sales to accomplish the necessary reduction. Also, EPA proposed, at this time, a comprehensive set of regulations for the control of hydrocarbon emissions from stationary sources to replace the stationary source control regulations proposed by the State. This step was necessary, in part, because only transportation and land use controls may be submitted in proposed form (40 CFR 51.22). The final plan comprising strategies proposed by Colorado and EPA was published in the Federal Register of August 2, 1973.

This draft of the Environmental Impact Statement considers the two fundamentally different situations, or "plans" outlined in Table 16. The first, or No Action Plan, assumes that no additional action will be taken for the specific purpose of lowering ambient concentrations of carbon monoxide and hydrocarbons. Under this assumption it was originally felt that the only significant reduction in vehicular emissions would be brought about by the FMVCP. The assessment of the air quality problem in Denver presented in Section III was based on this assumption. The implementation of the RTD Transportation Plan, financial support for which was authorized by the State referendum of September 7, 1973, would however, impact on the Denver area in a number of ways. It has therefore been included as one of the two possible developments under the No Action plan. The second plan is the Colorado/EPA 1977 Plan, published in the Federal Register.

At the present time sufficient high-altitude test data do not exist to justify the selection of a retrofit device or a particular inspection/maintenance program for inclusion in a transportation control plan. Accordingly, the Colorado/EPA 1977 Plan includes a major effort to develop a suitable retrofit device for pre-1968 vehicles, high altitude modification and tuning specifications and a high altitude inspection/maintenance

TABLE 16. Alternative Transportation Plans

NO ACTION	COLORADO/EPA 1977 PLAN (Federal Register, Aug. 2, 1977)
Possible Developments A. No Significant Action 1. Federal Motor Vehicle Control Program (FMVCP) continues 2. Recent trends in vehicular usage continues B. 1. FMVCP continues 2. RTD Transportation Plans for a. Early Action Program (bus) and b. Personal Rapid Transit (PRT) are implemented on schedule.	Tabulation of Strategies A. Strategies Proposed by Colorado in Plan Submitted on June 4, 1973 1. Semi-annual inspection and maintenance* of all light-duty vehicles registered in the AQCR using the idle test mode. (First cycle completed by 1 December 1975) 2. Air bleed retrofit* for all pre-1968 light-duty vehicles registered in the AQCR. (To be completed by 1 July 1976) 3. High altitude modification and tuning* of all 1968-1974 light-duty vehicles registered in the AQCR. (To be completed by 1 July 1976) 4. Improvements in public transit. 5. Expanded bikeway development. B. Strategies Proposed by Colorado in Supplemental Submitted on July 16, 1973. 1. Designation of mandatory bus/carpool lanes 2. Limitation on the construction of future parking facilities 3. Removal of on-street parking in the core area These three strategies are to be implemented by Dec. 1, 1974)

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* Inspection and maintenance procedures and approved retrofit devices are to be determined by a joint Colorado/EPA research program.

TABLE 16. Alternative Transportation Plans
(continued)

NO ACTION	COLORADO/EPA 1977 PLAN (Federal Register, Aug. 2, 1977)
	Tabulation of Strategies C. Additional Proposals by EPA for AQCR 1. Stationary source emission controls for hydrocarbons (Sources to be controlled are: dry cleaning, degreasing operations, organic solvent usage, petroleum products storage, organic liquid loading, gasoline transfer vapor control, filling auto tanks, paint and varnish manufacturing) 2. Gasoline limitation ● Beginning July 1, 1974, gallonage to be restricted to amount delivered during base year (July 1, 1972-June 30, 1973) ● Beginning May 31, 1977, total gallonage to be restricted as required to prevent standards from being exceeded.

program. Currently the airbleed to intake manifold system appears to be the preferred retrofit device for pre-1968 vehicles, and it has been included in the plan for an evaluation of its environmental impact.

APPENDIX A

SOCIAL ATTITUDINAL SURVEY

A questionnaire was distributed in seven major United States metropolitan areas for the purpose of gaining insight to public attitudes towards air pollution and transportation control measures designed to reduce air pollution. The survey was conducted with the assistance of a professional market research group, Market Facts, Inc., which maintains standing panels of households in each major metropolitan area; each representing a broad cross-section of households in the given area. The seven metropolitan areas surveyed include: (1) Dayton, Ohio, (2) Denver, Colorado, (3) Houston, Texas, (4) Los Angeles, California, (5) New York City, New York, (6) Philadelphia, Pennsylvania, and (7) Phoenix, Arizona. A summary of the attitude survey results is presented here, followed by a summary of the specific questionnaire responses in Denver, Colorado.

Summary of Major Findings from Public Attitude Survey on Air Pollution and Transportation Control Measures in Seven Major U.S. Metropolitan Areas*

A. Auto Air Pollution

1. About 85-90 percent of all respondents in all cities feel auto air pollution is a serious or very serious nationwide problem. This feeling is highest in Denver (94%) and lowest in Houston (85%).
2. Respondents in all seven cities feel that auto air pollution is a more serious problem nationwide than it is locally.
3. A law requiring auto emission control equipment on all pre-1975 cars is much more acceptable at a government subsidized cost of $50 than a non-government subsidized cost of $200. Regardless of the cost, this law is viewed more favorably by respondents in New York and Philadelphia. A law requiring inspection of this equipment is also viewed more favorably by respondents in New York and Philadelphia. Respondents in all cities feel the cost of this inspection should be under $9.00.
4. In all cities the two most acceptable proposals for controlling auto air pollution are "prohibit traffic/parking in central business districts" and "create car pool/bus only lanes on major thoroughfares." The two most unacceptable are "gasoline rationing" and "500 registration fee for each auto."
5. Interest in car pools as a means of reducing auto air pollution is about 40-50 percent of the respondents in each city; but

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*Dayton, Ohio; Denver, Colorado; Houston, Texas; Los Angeles, California; New York City, New York; Philadelphia, Pennsylvania; Phoenix, Arizona the prospect of joining one or organizing one is viewed as difficult by 75-85 percent of non-car pool riders.

6. The prohibition of parking, loading and unloading on busy streets is rated as being very effective or somewhat effective by respondents in New York (90%) and Dayton (98%) in reducing traffic congestion. Respondents in the remaining cities feel that improving the timing of traffic signals would be the best way to reduce traffic congestion. All cities agree that widening major streets at intersections would be the least effective way of reducing traffic congestion.

B. Transportation Usage

1. Public transportation usage is highest in New York (229 trips per household per year) and Philadelphia (135). The remaining cities are much lower in usage (under 40).
2. Reasons for public transportation usage vary by city. Overall it is used in New York and Philadelphia because it's cheaper and faster. In Denver it's used because it's cheaper and less congested. In Los Angeles it's used out of necessity (no car available or no drivers license). Reasons for usage in other cities vary.
3. Reasons for auto usage are the same in all cities - faster, more flexible, more available.
4. The most effective proposals for encouraging usage of public transportation facilities tend to be similar to the reasons people travel by auto -- more frequent service, faster travel,

more conveniently located stops and stations, and lower fares. This is true for almost all seven cities.

5. In all cities there is substantial reluctance (66% or higher) to disposing of any car or cars even if public transportation was improved.

In Denver, Colorado, 204 usable automobile air pollution questionnaires were returned from the panel of residents contacted in the Denver Metropolitan Area. The sample was selected to be representatives of the population of the area in terms of income level and age. Annual family income (1971) of respondents was:

Less than $8,000	35%
$8,000-$15, 000	46%
More than $15,000	19%

Their home locations were distributed as follows throughout the Denver Metropolitan Area:

Location	Number of Respondents	Percent of Total
Denver	98	48
Lakewood	21	9
Arvada	11	5
Longmont	9	4
Boulder	8	4
Evergreen	7	3
Littleton	7	3
Aurora	6	2
Wheatridge	6	2
Englewood	6	2
Other Communities	35	17
	204	100

Each respondent was asked to indicate the number of autos owned in his household. Answers were as follows:

No car	2%
One car	30%
Two cars	50%
Three or more cars	18%

Questionnaire responses were tabulated by income level and car ownership status of each panel member's family. Results of the survey follow with appropriate explanatory notes.

Results of Questionnaire on Public Attitude Toward Air Pollution and Transportation Control Measures in the Denver Metropolitan Area

1. **All autos made in 1975 and thereafter will be equipped with emmission control devices to reduce air pollution. If in 1975 you owned a car built before that year, how would you feel about a law requiring you to put emission control equipment which might cost $200 on your car? ("X" BELOW)**

2. **How would you feel about this law if the cost was reduced by government subsidy to about $50? ("X" BELOW)**

Feeling Toward Law:	(165R)* 1. Cost $200	(201R) 2. Cost $50
Very much in favor of law. .	10.3%	49.8%
Somewhat in favor of law. . .	20.6	23.4
Somewhat against law.	15.2	11.4
Very much against law.	53.9	15.4

3a. **Even cars properly equipped with emmision control equipment might still pollute the air if the equipment was not properly maintained. How would you feel about a law requiring periodic inspection of the emission control system to assure that it was working properly? ("X" ONE ONLY)**

Very much in favor of law	Somewhat in favor of law	Somewhat against law	Very much against law
59.1%	26.1%	8.4%	6.4%

3b. **Assuming you had to have your car inspected at least once a year, what would you consider a reasonable cost for the inspection? (WRITE IN AMOUNT)**

$ 4.58 (mean)

Five percent of the respondents answered "nothing" to this question. The most frequent response (29.1%) was $2.00, followed by 21.4 percent of the panel who answered $5.00 and 18.9 percent felt that $1.00 was an appropriate charge. The following is a tabulation of the mean value by car ownership status of the panel member's family.

No car	$32.83
One car	4.46
Two cars	3.36
Three or more cars	5.28

3c. **Assuming you had to have your car inspected at least once a year, where do you think the inspection should be made? ("X" ONE ONLY)**

At state-operated inspection centers.	35.8%
At city-operated inspection centers.	7.8
At local service stations or garages	52.5
At some other place (Specify):	3.9

The "other" responses to this question were varied. A few members of the panel suggested that inspection should be accomplished and supervised by the State at various locations.

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*-Indicates number of respondents. (165R) = 165 respondents.

4a. Even if all autos were equipped with properly maintained emission control systems, some cities might still have auto air pollution problems due to the large number of cars either on the streets at the same time or concentrated in particular areas. Listed below are several possible ways to reduce pollution under one or both of these conditions. Please tell me how you feel about __each__ of these proposals. ("X" ONE ON EACH LINE)

+2 +1 0 0 -1 -2

	To Me This Plan Is:				
__Proposal__	Very Acceptable	Somewhat Acceptable	Neither Acceptable Nor Unacceptable	Somewhat Unacceptable	Very Unacceptabl
a. Gasoline rationing	2.9	6.9	6.4	12.7	▲ 71.1
b. Very high ($500) registration fee per auto	0.0	1.0	5.5	7.0	86.▲6
c. Very high ($500) registration fee per auto but only for the second, third, etc., auto	4.0	10.0	7.0	19.9	▲ 59.2
d. Prohibit traffic and parking in central business districts	33.3	▲ 30.4	8.8	16.7	10.8
e. A tax on __all day__ parking in central business districts	18.2	27.1	12.3	▲ 12.3	30.0
f. A tax on parking in central business districts regardless of whether a person parked only one hour or all day	10.0	15.0	14.5	▲ 18.5	42.0
g. Tolls on exit ramps of major freeways and expressways	2.5	5.4	13.9	18.8	▲ 59.4
h. Tolls on exit ramps of major freeways and expressways but only when traffic was heavy	3.5	9.4	8.9	17.8	▲ 60.4
i. Restrictions on non-essential auto travel during times of high pollution by issuance of special license plates or vehicle stickers	13.3	27.6	9.4	▲ 12.3	37.4
j. Turn some existing lanes into "bus only" and "car pool only" lanes on major expressways and streets	34.8	▲ 26.5	10.8	9.3	18.6

▲- Indicates the weighted means for each answer.

4b. Which of the proposals listed above would be the __most acceptable__? (Give Letter:) __d - 35.0%__ __j - 34.0%__

4c. Which would be __most unacceptable__? (Give Letter:) __b - 53.8%__ __a - 32.7%__

QUESTIONS 5-8 ASK FOR INFORMATION RELATING TO OTHER HOUSEHOLD MEMBERS. CONSULT THEM, IF NECESSARY, FOR THE ANSWERS.

5a. **How often do the various members of your household travel by public transportation? (For example, by bus, subway, or commuter train.)**

	Husband	Wife	Children (Over 16 Years Old)
Three or more times a week.	1.6%	2.0%	5.4%
One or two times a week.....	1.6	3.0	1.8
Once a month...............	3.8	5.0	2.7
Once every three months	2.7	13.4	1.8
Never	86.8	76.6	49.0
No household member	3.3	0.0	39.3

5b. Please rate each household member's reason for using public transportation. (Rate the most important reason "1", the next most important "2", the next "3", etc. If a household member never uses public transportation, "X" the "never use" box at the bottom of the list.)

5c. Please rate each household member's reasons for traveling by auto. Follow the same procedure as in Question 5b. (WRITE IN BELOW UNDER 5c)

	CONCENSUS RATING					
	5b. Public Transportation			5c. Auto Transportation		
Reasons	Husband	Wife	Children (Over 16 Years Old)	Husband	Wife	Children (Over 16 Years Old
a. Cheaper				7	6	7
b. Faster				3	3	3
c. More comfortable ..				5	5	6
d. Safer for passenger.				8	8	8
e. Less congested.....				6	6	4
f. More available.....				1	1	2
g. More flexible (I can come and go as I please).........		SEE COMMENTS		2	2	1
h. More relaxing (able to read while traveling)........				----NOT APPLICABLE-----		
i. Need car during the day.............				4	4	5
j. I do not have a driver's license..				----NOT APPLICABLE-----		
k. Car is not available when I need it....				----NOT APPLICABLE-----		
l. Other (Specify):				SEE COMMENTS		
m. Never use ("X" Box)	160/178	155/202	55/68	3/178	9/202	13/68

Comment on Question 5b

There were too few responses to draw meaningful conclusions from this question.

Comment on Question 5c

Respondents indicated that one of the main reasons for driving was lack of mass transit near their residence.

5d. Again, consulting other members of your household, please rate in order of effectiveness which items below you feel would be most effective in encouraging the use of public transporation. (Rate the most effective item a "1", the next most effective "2", the next "3", etc.)

	CONCENSUS RATING		
Items:	Husband	Wife	(Over 16 Years Old) Children
Cleaner and newer vehicles. .	7	8	8
Faster travel	3	3	2
Air-conditioned vehicles	9	9	9
More frequent service	1	1	1
Lower fares	5	4	3
Parking facilities at stops or stations	4	5	5
Shelters against bad weather at stops or stations	6	6	6
Better security to assure personal safety.	7	7	7
More conveniently located stops and stations	2	2	4
Other (Specify):			

6a. How would you or other household members feel about traveling to and from work in a car pool? ("X" ONE ONLY)

Very interested	19.4%
Somewhat interested	31.1
Not at all interested	32.7
Already in car pool	6.1
Do not travel to and from work by car.	10.7

6b. If it became necessary to restrict the number of cars on expressways and streets in order to reduce pollution and car pools became necessary, how difficult do you think it would be to get into one an existing one or organize one amongst your friends, neighbors and/or work associates. ("X" ONE ONLY)

Extremely difficult	31.3%
Very difficult	11.3
Somewhat difficult	28.1
Somewhat easy	14.4
Very easy	7.2
Extremely easy	2.1
Already in car pool	5.6

7. One of the major causes of areas of high pollution is traffic congestion. Pollution could be reduced if traffic congestion and stop-and-go traffic was reduced. Listed below are several ideas for reducing traffic congestion. Please tell me how effective you think each of these ideas would be in reducing congestion and pollution. ("X" ONE BOX FOR EACH IDEA)

+2 +1 0 0 -1

Idea:	Very Effective	Somewhat Effective	Not Effective At All	Would Increase Congestion
a. Prohibit parking, loading and unloading on busy streets	49.0 ▲	42.9	6.1	2.0
b. Increase the number of one-way streets	28.1 ▲	53.6	17.3	1.0
c. Establish reversible lanes on busy streets to be used during rush hours	19.8	▲ 43.1	17.3	19.8
d. Prohibit turns at busy intersections during rush hours	38.5 ▲	34.4	18.5	8.7
e. Widen major streets	40.2 ▲	37.6	17.5	4.8
f. Widen major streets at intersections only	6.8	43.7 ▲	35.3	14.2
g. Provide pedestrian underpasses and/or overpasses	42.6 ▲	38.1	18.3	1.0
h. Improve timing of traffic signals	67.7 ▲	27.7	4.6	0.0
i. Increase the number and frequency of radio traffic reports	13.0	▲ 59.6	25.9	1.6
j. Turn some existing lanes into "bus only" and "car pool only" lanes on expressways and busy streets	34.4 ▲	43.1	12.8	9.7

Your ideas (Please List): ▲- Indicates the weighted mean for each answer.

Several comments and ideas were expressed with regard to the above question. Some panel members feel that mass transit will solve much of the pollution problem. Others thought that if the core area, or downtown, was made a vehicle-free zone, it would help decrease pollution and improve pedestrian circulation.

8. Since traffic congestion is most severe at times when people are going to or coming from work, one alternative for reducing congestion would be to have people start and stop work at different times of the day. That is, some people would start work at 5:00 AM and quit at 2:00 PM, others would work from 7:00 AM to 4:00 PM, others from 10:00 AM to 7:00 PM, etc. How do you feel about this idea? ("X" ONE ONLY)

Very much in favor	33.3%
Somewhat in favor	31.3
Indifferent	15.7
Somewhat opposed	12.1
Very much opposed	7.6

9a. **Please record the model year of each car owned in your household. (WRITE IN BELOW UNDER 9a)**

9b. **Please estimate the number of miles each car was driven in the last year. (WRITE IN NUMBER OF MILES UNDER 9b BELOW)**

9c. **For each car, please estimate what percentage of last year's mileage was accounted for by driving outside your local metropolitan area. (For example, vacation, business trips, short weekend trips, etc.) (WRITE IN BELOW UNDER 9c)**

	9a. Model Year	9b. Last Year's Mileage	9c. Percentage of Mileage Outside Local Area
Car #1	1969	10,935	29
Car #2	1967	9,056	27
Car #3	1966	7,279	26
Car #4	1966	4,500	21

9d. How many licensed drivers are there in your household? (WRITE IN)

Number of Licensed Drivers: 2.1 (Avg.)

9e. **If better public transportation were available, would you consider disposing of any of the cars you own?**

Yes	11.2%
Maybe	22.4
No	66.4

9f. How many? (WRITE IN) 1.1 cars

10a. **Overall, how serious a problem do you think auto air pollution is in your city? ("X" ONE BOX UNDER 10a BELOW)**

10b. **Overall, how serious a problem do you think auto air pollution is nationwide? ("X" ONE BOX UNDER 10b BELOW)**

	10a. City	10b. Nationwide
Very serious problem	39.3%	55.1%
Serious problem	29.9	39.4
Slightly serious problem ...	24.4	4.5
No problem at all	6.4	1.0

11. **If you have any views or comments regarding any question or idea, please record them:**

Fourty-seven respondents (23 percent of the panel) added comments at the end of the questionnaire. Fifty percent of the comments were in favor of a better mass transit system for the area to help reduce the need for private cars. Twenty percent felt that older cars, buses and trucks contribute more to the pollution problem than cars. The remainder thought that if laws were enforced to reduce industrial pollution, the problem would be solved.

APPENDIX B

ADDITIONAL STATIONARY SOURCE CONTROLS FOR HYDROCARBON EMISSIONS

Evaluative state-of-the-art information on control measure options for eight major classes of stationary hydrocarbon sources follows. The information provided for each HC source class includes: (1) control(s) description(s); (2) pollutant reduction potential; (3) time to implement, (4) technical feasibility; (5) expected cost to implement, both direct and indirect; (6) social impact/acceptability; and (7) location affected -- availability/applicability. The following classes of stationary hydrocarbon sources are examined:

1. Degreasing operations
2. Dry Cleaning operations
3. Graphic arts operations
4. Industrial surface coating
5. Petroleum refineries
6. Gasoline sales and distribution
7. Petroleum products liquid storage
8. Petrochemical manufacture

Control Measure Analysis

1. Degreasing Operations Controls: Degreasing is a term broadly applied to the use of organic solvents (primarily organic solvents) to dissolve and remove soils from metal objects. If the solvent is maintained at its atmospheric boiling point in the process equipment, the cleaning process is referred to as "vapor degreasing" as opposed to cold solvent cleaning. The basic vapor degreaser consists of an open tank equipped with a liquid heater, a vapor zone above the liquid surface, and a narrow water-cooled jacket near the top of the tank to control the vapor zone.

Most control efforts have been directed to prevention of emissions at the tank rather than controlling exhaust gases. Three primary control approaches include (1) carbon adsorption systems, (2) refrigerated cooling jacket, and (3) improved operating techniques to prevent open top emissions (temperature control instrumentation).

Pollutant Reduction Potential

1. Carbon Adsorption - 90%
2. Refrigerated cooling jacket - 10%
3. Improved operation to prevent open top emissions - 20-30%

Time to Implement

Short term -- installation of control hardware and for process modification.

Technical Feasibility

All controls are technically feasible, but individual process modification and retrofiting must be evaluated. Not all degreasers can be properly vented to capture all of the evaporated solvent.

Expected Cost to Implement

a. Direct Cost

NOTE: A basic degreaser unit cost is about $2,000

Control Measure	Capital Cost	Net Annual Cost or Saving
(1) Carbon Adsorption	$19,500	$ 620 (cost)
(2) Temperature control plus good operation	$ 300	$1,428
(3) Temperature control plus good operation plus refrigerated coils	$3,000	$1,070

b. Indirect Cost

Maintenance and operation of control equipment (marginal)

Social Impact/Acceptability

Degreasing operators should be willing to adopt and install temperature control and good operation since an annual saving results from collected vapors and efficient operations. Plant operators may not willingly employ refrigerated coils or carbon adsorption due to the large capital cost relative to the cost of the degreaser unit.

Location Affected -- Availability/Applicability

General applicability to all degreasers independent of physical location.

2. Dry Cleaning Operations Controls: Industrial dry cleaners primarily use two types of solvents: (1) petroleum solvents called "Stoddard solvents,and (2) perchloroethylene called "Perc." Stoddard solvent has a value of $0.25/gallon and Perc has a value of $1.39/gallon, diminishing incentives to develop Stoddard recovery systems. Generally the Stoddard plant is a washer-extracter type equipment with a regenerative filter, while Perc plan is a unitized dry-to-dry system equipped with a condenser, regenerative filter, and cooler.

Carbon adsorption is the major control measure applicable to Perc dry cleaning plants but control of emissions from Stoddard plants is not straightforward. Carbon adsorption is still in development stages, and substitution of perchloroethylene for Stoddard may be impractical at some plants due to equipment differences.

Pollutant Reduction Potential

Perc dry cleaning -- carbon adsorption: 98% removal of solvent vapors

Stoddard dry cleaning -- carbon adsorption: 90% removal

Time to Implement

Perc - short term: time to retrofit plant with carbon adsorption

Stoddard - short term: retrofit with carbon adsorption
long term: conversion to Perc

Technical Feasibility

Perc - carbon adsorption control presently feasible

Stoddard - carbon adsorption control still in developmental stage. Conversion to Perc feasible presently

Expected Cost to Implement

a. Direct Cost

(1) For a Perc plant handling 500 lb/day of clothing, a carbon adsorber would cost about $1,400. The value of the recovered solvent would just offset the annual costs for this equipment.

(2) For a Stoddard plant handling 2000 lb/day of clothing, a carbon adsorption system is estimated to be $17,000. After taking account for recovered solvent, the net annual cost based on a one-shift operation is $2,100 or about $0.022 per pound of solvent recovered. Rough estimates for converting Stoddard to Perc are about $30,000 per plant since all conventional Stoddard plant equipment would have to be replaced.

b. Indirect Cost

Maintenance and operation of control equipment, increase retail cost of dry cleaning.

Social Impact/Acceptability

Perc plant -- since there would be no net annual cost to the owner for the installation and operation of a carbon absorber, acceptability should be positive. For a Stoddard plan, due to higher costs and uncertainty, control measure acceptability would appear to be absent by the plant owner and dry cleaning customer since increased costs would, if possible, be reflected in service charges.

Location Affected -- Availability/Applicability

Generally applicability to all Perc dry cleaners, with more specific and source determinant for Stoddard dry cleaning plants.

3. Graphic Arts Operation Controls: In this industry printing consists of several operations including gravure, flexography, lithography, letter press, screen, and metal decorating. Hydrocarbons are emitted primarily from operations that utilize inks containing 55 percent or more organic solvent (alcohol, ester, etc.)

Major emissions control measures with differing applicability include: (1) use of after burners, (2) adsorption, and (3) process and input changes. Presently several material and process variations are under investigation or development (such as ink reformulations and drying technique modification), but are not available for immediate use.

Pollutant Reduction Potential

(1) Thermal Incineration: Efficiency ranges from 95 to 99 percent. Can be used to control emissions from all printing processes but it is more adaptable for those that use ovens to evaporate solvent from ink or coating.

(2) Catalytic Incinerator: Efficiency ranges from 80 to 85 percent. Can be used by all printing processes that use ovens to evaporate solvents.

(3) Adsorption: Efficiency ranges from 95 to 99 percent. This system is practical only for processes where emitted solvent has not been partially oxidized and is generally not adaptable to dryers or ovens.

It is not possible at this time to predict the effectiveness of other potential or developing control measures.

Time to Implement

Hardware devices - short term: installation time

Process changes - variable short term

Technical Feasibility

Afterburners and adsorption control measures presently applicable. Other methods are in developmental stages.

Expected Cost to Implement

a. Direct Costs

Control costs to operator are estimated for those processes which can be controlled by thermal or catalytic afterburners. Accurate prediction of processes and other control measures are not possible presently.

The afterburner control costs shown below are typical of a wide range of process variables but substantial deviations may occur in application.

Control Costs for Afterburners in the Graphic Arts Industry

Process	Web Offset or Heat Set Letter Press		Metal Decorating	
Emissions (lbs of carbon/hr)	5		40	
Gas volume (scfm)	5,000		10,000	
Control device	Thermal Incinerator	Catalytic Incinerator	Thermal Incinerator	Catalytic Incinerator
Operating time (hr/yr)	1,300	1,820	4,160	4,160
Capital Cost ($)	31,000	50,000	48,000	70,000
Annual Cost ($/yr)	13,500	12,900	55,200	27,100
Annual Cost per pound carbon removed ($/lb)	2.08	1.98	.33	.16

b. Indirect Cost

Increased cost to consumer of graphic art services and/or quality of service changes.

Social Impact/Acceptability

Present afterburner control technology is relatively costly, and operator acceptance may not be high. New process and system modification developments should cost less than afterburners, and therefore may be more acceptable.

Location Affected -- Availability/Applicability

General applicability to graphic arts processes, with location specific variations in retrofit requirements.

4. Industrial Surface Coating Controls: Surface coating includes many processes which apply a protective and/or decorative coating of hydrocarbon solvent-based paint on manufactured parts. Some hydrocarbons are emitted from spraying, while much of the solvent is evaporated in the drying step.

Incineration and adsorption are feasible methods of HC_x control in stack gases while other control measures may be categorized as process changes. Several process change measures include water-based formulations, powder coatings, and high-energy curing.

Pollutant Reduction Potential

No estimate available.

Time to Implement

Short term: variable based on retrofit requirements. Process changes being investigated may be more permanent long-term solutions.

Technical Feasibility

Incineration and adsorption are feasible stack gas control measures but adsorption is seldom used. Process changes are in various stages of development and employment.

Expected Cost to Implement

a. Direct Cost

The costs of incineration are a function of the stack gas volume. Estimated capital cost for air incineration on a large wet paint line emitting about 45 pounds per hour is about $390,000. Data for smaller operations are similar to those costs shown for the graphic arts industry.

b. Indirect Cost

Higher final product and intermediate product prices; i.e., consumer and manufacturers price increases.

Social Impact/Acceptability

High investment costs for incineration equipment and demand for large quantities of natural gas make this measure unattractive. Process changes and modifications may become more acceptable but lead time requirements may offset lower costs in overall acceptability.

Location Affected -- Availability/Applicability

Incineration is universally applicable to stack gas controls with differential retrofitting requirements. Process changes may be more location specific.

5. Petroleum Refinery Controls: There are many sources of hydrocarbon emissions in a petroleum refinery, prominent of which include waste water collection and disposal systems, blowdown systems, catalyst regenerators, pumps, valves, vacuum jets, high pressure handling of volatile hydrocarbons, compressors, heaters, and boilers.

Control equipment measures combined with good operation and maintenance measures are available for new refiners and for retrofitting existing plants. Incineration, mechanical sealing, and other measures exist and are employed.

Pollutant Reduction Potential

No estimate available.

Time to Implement

Short-term retrofitting requirements varying with specific source.

Technical Feasibility

Control equipment available for many sources. Proper operation and maintenance required.

Expected Cost to Implement

a. Direct Cost

Variable

b. Indirect Cost

Increased product price, reduction, and potential delay in fuel availability.

Social Impact/Acceptability

Pollution controls may improve the public acceptance of new oil refinery locations in certain areas, and therefore, control equipment and operating expenditures would be acceptable to refinery operators.

Location Affected -- Availability/Applicability

General applicability.

6. Gasoline Sales and Distribution Controls: Hydrocarbon losses from the bulk terminal to the service station and then to individual vehicles are among the greatest from stationary sources.

Maximizing control efficiency requires control measures at the service station, which in turn requires installation of vapor recovery equipment to bulk terminals. The most attractive potential methods to reduce emissions from these sources include the following sequence of control measures:

Phase I (55 percent control):

(1) Install equipment at service station and modify tank trucks to recycle vapor displaced from underground storage tanks back to the tank truck during fuel drop to the underground tank.

(2) Install vapor recovery systems to recover vapors captured at the station when reloading at bulk plants and terminals.

Phase II (30 to 35 percent control long range):

(1) Install special dispensing nozzles and hoses and vapor return lines to return vapors displaced from refueling automotive fuel tanks to underground storage tanks.

(2) Install packaged vapor recovery equipment at the service station, if necessary, to achieve a minimal overall recovery of 90-percent recovery at the service station.

Pollutant Reduction Potential

Projected Potential:

Phase I control measures 55 percent
Phase II control measures 30 to 35 percent
Total of 85 to 90 percent

Time to Implement

Phase I: Short term with complete compliance up to several years.

Phase II: Intermediate - more time required because of percent development stage and need for additional testing.

Technical Feasibility

Phase I:

(1) Service station recycle is feasible and has been demonstrated.

(2) Vapor recovery systems at bulk terminals have proven feasible during warm weather operations, but operability and safety in cold weather are still being tested.

Phase II:

The technological feasibility has been demonstrated but implementation may be serveral years for several reasons. The canister and refrigeration approaches are limited in supply. Special vapor return nozzles which could produce a tight fit at service station gas filling operations are still in development stages.

Expected Cost to Implement

a. Direct Cost

Predicted costs for a theoretical service station dispensing 25,000 gallons/month of gasoline are:

Control Costs per Service Station Dispensing 25,000 gallons/month of Gasoline

Phase I -- Recycle from Underground Tank to Truck and Bulk Terminal Vapor Recovery (55 Percent Reduction in HC_x Emissions)

	Recycle Vapor to Tank Truck	Vapor Recovery at Bulk Terminal	Phase I Total
Capital/Station	$1,073	$783	$1,856
Emission Reduction/ Station	1,933 lb/yr 372 gal/yr	1,733 lb/yr 334 gal/yr	3,666 lb/yr 706 gal/yr
Annual Cost/Station			
Total	$97/yr	$70/yr	$167/yr
Per lb recovered	$0.05/lb	$0.04/lb	$0.045/lb
Per gal pumped	$0.03/gal	$0.02/gal	$0.055/gal

Phase II -- Canister or Refrigeration (35 Percent Reduction in HC_x Emissions)

	Canister	Refrigeration
Capital/Station	$6,090	$12,678
Emission Reduction/Station	2,300 lb/yr 443 gal/yr	2,300 lb/yr 443 gal/yr
Annual Cost/Station		
Total	$1,298/yr	$2,693/yr
Per lb recovered	$0.56/lb	$1.17/lb
Per gal pumped	$0.43/gal	$0.89/gal

Phase I & Phase II -- Canister or Refrigeration (90 Percent Reduction in HC_x Emissions)

	Canister	Refrigeration
Capital/Station	$7,946	$14,534
Emission Reduction/Station	5,966 lb/yr 1,149 gal/yr	5,966 lb/yr 1,149 gal/yr
Annual Cost/Station		
Total	$1,456	$2,860
Per lb recovered	$0.24/lb	$0.48/lb
Per gal pumped	$0.48/gal	$0.95/gal

b. Indirect Cost

Increased gasoline costs to consumer.

Social Impact/Acceptability

Operator acceptability will be based on total capital investment requirements and ability to pass add costs on to gasoline consumers. Consumer impacts of Phase I in terms of increased projected gas costs are not severe, but Phase II costs projected imply large potential price increases which may alter mobility and mode of travel in various regions of the nation.

Location Affected -- Availability/Applicability

Technology universally applicable but spatial variation in equipment suppliers and vendors of control hardware/systems.

7. Petroleum Products Liquid Storage Controls: Storage tank evaporative emissions occur in all phases of the petroleum industry and rank among the highest from industrial sources. HC_x emissions from storage tanks are of three classes: (1) breathing losses, (2) working losses, and (3) standing storage losses.

The control measure most commonly used for volatile organic compounds is the floating roof tank. Beyond a vapor pressure of 11.0 psia, more effective control measures are needed, including (1) pressure tanks, and (2) vapor recovery systems.

Pollutant Reduction Potential

Floating Roof Tanks: 90 to 92 percent reduction
Vapor Recovery Systems: 92 to 95 percent reduction

Time to Implement

Short term: time to construct new storage facility
or retrofit existing tanks.

Technical Feasibility

Internal floating roof covers available for small tanks, and covered floating roofs for intermediate size tanks. Large tanks usually use the external roof.

Expected Cost to Implement

a. Direct Cost

Cost of new and retrofitting floating roof tanks for storing petroleum products (such as gasoline) are shown below:

Investments - Floating Roof vs. Fixed Roof Tanks

Tank Size		Cost to Retrofit Fixed Roof to:		ΔCost for New Construction Floating Roof Type vs. Fixed Roof		
Diameter in Feet	Nominal Capacity bbls[a]	Covered Floating Roof	Internal Floating Cover	External Pontoon Floating Roof	Covered Floating Roof	Internal Floating Cover
20	1,100	---	$ 2,800	---	---	$ 2,800
40	9,000	$17,000	$ 6,000	---	NA	+ $ 7,000
60	22,000	$26,000	$12,000	+ $20,000	+ $17,000	+ $12,000
90	54,000	$42,000	$22,000	+ $25,000	+ $23,000	+ $24,000
110	80,000	$53,000	$40,000	+ $27,000	+33,000	---

[a] 42 gal/bbl

Control costs for storing a high volatile product (such as gasoline) vary from costs for storing a low volatile material (such as jet naphtha) as shown below:

Control Costs for Retrofitting Fixed Roof Tanks to Covered Floating Roofs

Product	Gasoline			Jet Naphtha		
Tank Size (10^3 bbls)	1.1	22	80	1.1	50	80
Investment Floating vs. Fixed (10^3\$)	2.8	26.0	53.0	2.8	26.0	53.0
Annualized Cost[a] (10^3\$)	(0.2)	(1.9)	(15.0)	0.3	2.4	2.8
Cost per gallon thruput-¢/gal	(0.03)	(0.03)	(0.03)	0.05	0.02	0.01

[a] Savings represented by parentheses.

b. Indirect Cost

General increased cost of petroleum products (minor).

Social Impact/Acceptability

Control of highly volatile products such as gasoline may result in product and dollar savings and make control attractive, while less volatile materials may not be conserved enough to cover equipment costs.

Location Affected -- Availability/Applicability

General applicability of control hardware, based on size of storage facilities.

8. Petrochemical Manufacture Controls; Carbon Black, Acrylonitrile, Formaldehyde, Ethylene Dichloride: Principal emissions from the manufacture of these materials include carbon monoxide and hydrocarbons.

Thermal and catalytic incinerators, waste heat boilers, plumer burners, and water or caustic scrubbers are primarily control measures for reducing HC_x emissions with up to 100 percent efficiency. In most cases the most efficient pollution control device is thermal incinerator followed by a waste heat boiler.

Pollutant Reduction Potential

HC_x control up to 100 percent efficiency.

Time to Implement

Short term - time to install control device(s) on process emission sources.

Technical Feasibility

Above mentioned control devices are all technically feasible, with differing applications based on new plant or retrofitting requirements.

Expected Cost to Implement

a. Direct Cost

Range from $50,000 to $1,200,000 capital and operating costs for optional process controls.

b. Indirect Cost

Product price increase range from 0.04¢ to 3.5¢ per pound of product.

Profit decrease from 0 to 20 percent for the various product manufacturers.

Social Impact/Acceptability

Social acceptability, influenced by product price impact, will vary based on the specific petrochemical. Manufacturer cooperation and willingness to comply are questionable due to the large capital equipment outlay required in most cases.

Location Affected -- Availability/Applicability

General applicability, with minor variations based on the type of petrochemical firm, and new versus old plant considerations.